Decision Support Systems for Improved Water Resources Management and Operations

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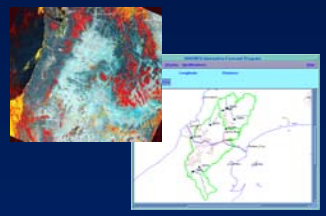
KENNEL
CLUB
Gaines St
NORTH
61
67

Experiences with DSS

- Different ways to approach the problem
- Planning examples – TVA, CRSS
- Operations example – Panama Canal

- State-of-the-art has shifted from only planning systems to include real-time operations too
- DSSs must be adaptable and robust

Decision Support System Conceptual Design

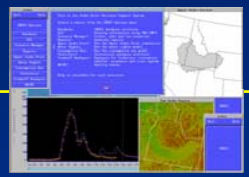


Hydrologic Forecasting
(Large river and ALERT systems)

Real-time
Data Collection

Consumptive Use
Modeling

Reservoir and
River Simulation/
Optimization for
Hydropower
Water Supply
Flood Control

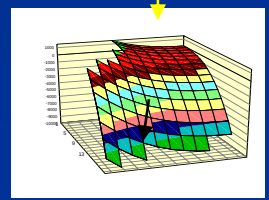


Graphical User
Interfaces

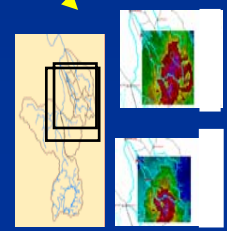
Database
Historical
Physical
Spatial
Policy
Parametric
Scenario
User
Real-time

Water Quality
Assessment

Meteorological and
Climate Models



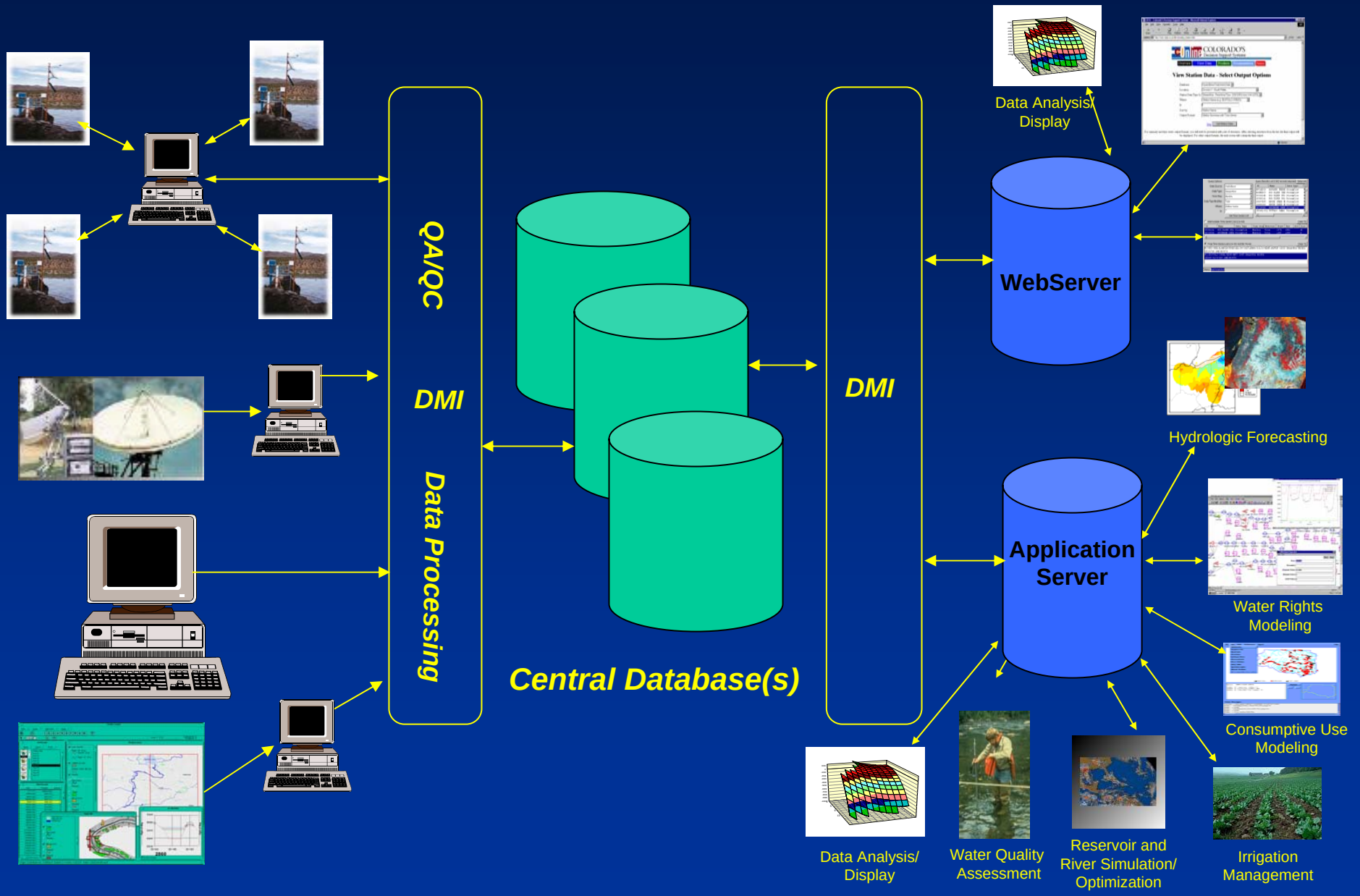
Data Analysis/
Display



Precipitation
Estimation

Irrigation
Management

Decision Support System



Data Issues

- Historical vs. Real-Time vs. Forecast Data
- Data quality control issues
- Scaling issues in space and time
- Need for archiving

Modeling Issues

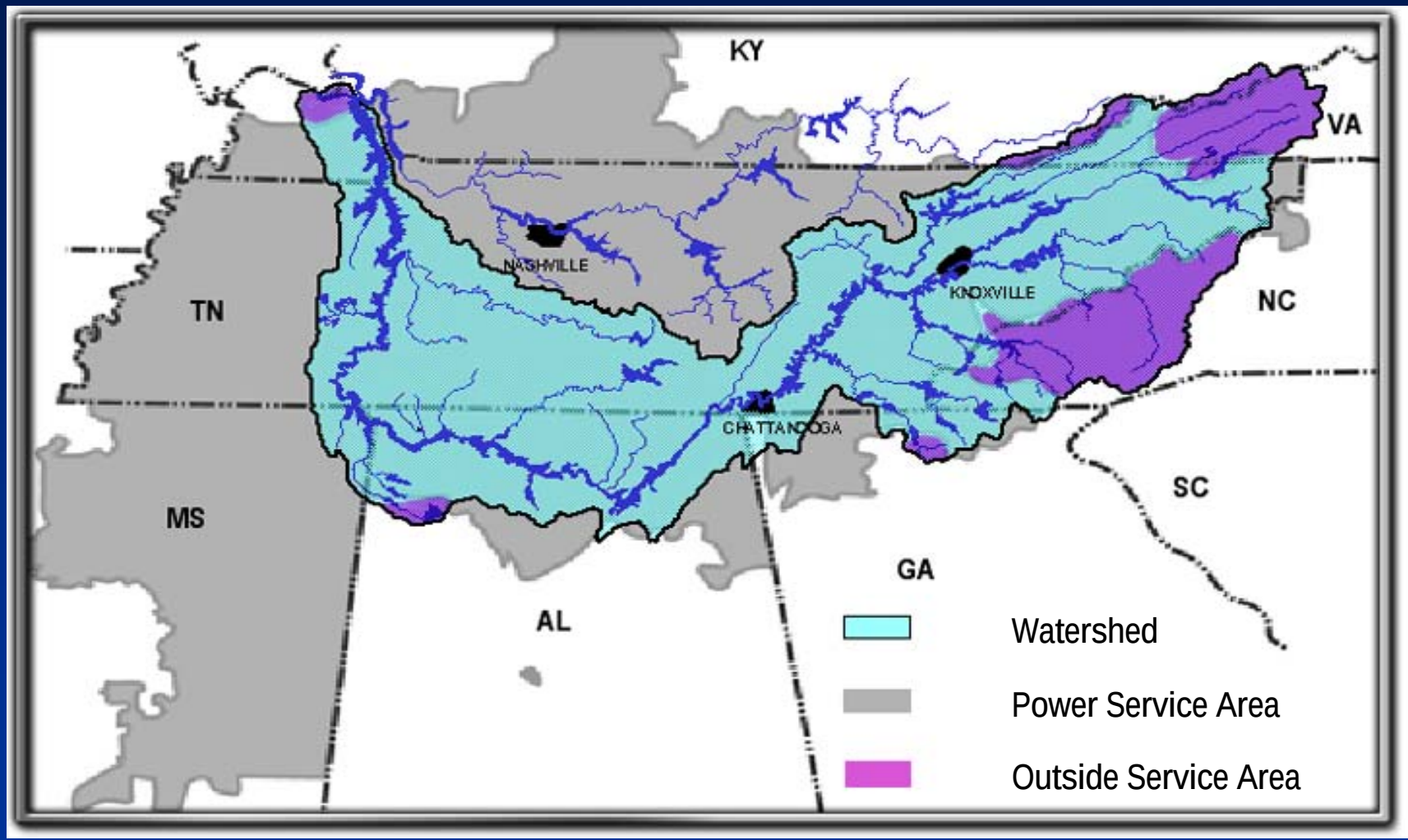
- Availability of applicable models
- Data storage requirements
- Data formatting
- Output requirements
- Planning vs. Operations

Model Types

- Planning Model
  - Uses historical inputs to the system
  - Attempts to simulate current conditions of the physical system
  - Allows for “what if” scenarios
  - Provides tools for assessment of scenarios

- Operations Model
  - Uses real-time or forecast inputs of precipitation and temperature
  - Reproduces most recent physical system states and forecasts
  - Allows for “what if” scenarios
  - Provides tools for assessment of scenarios

Planning Model Example -TVA



Tennessee Valley Authority

TVA is responsible for operation and maintenance of 49 dams

Tributary - Multipurpose
Hiwassee

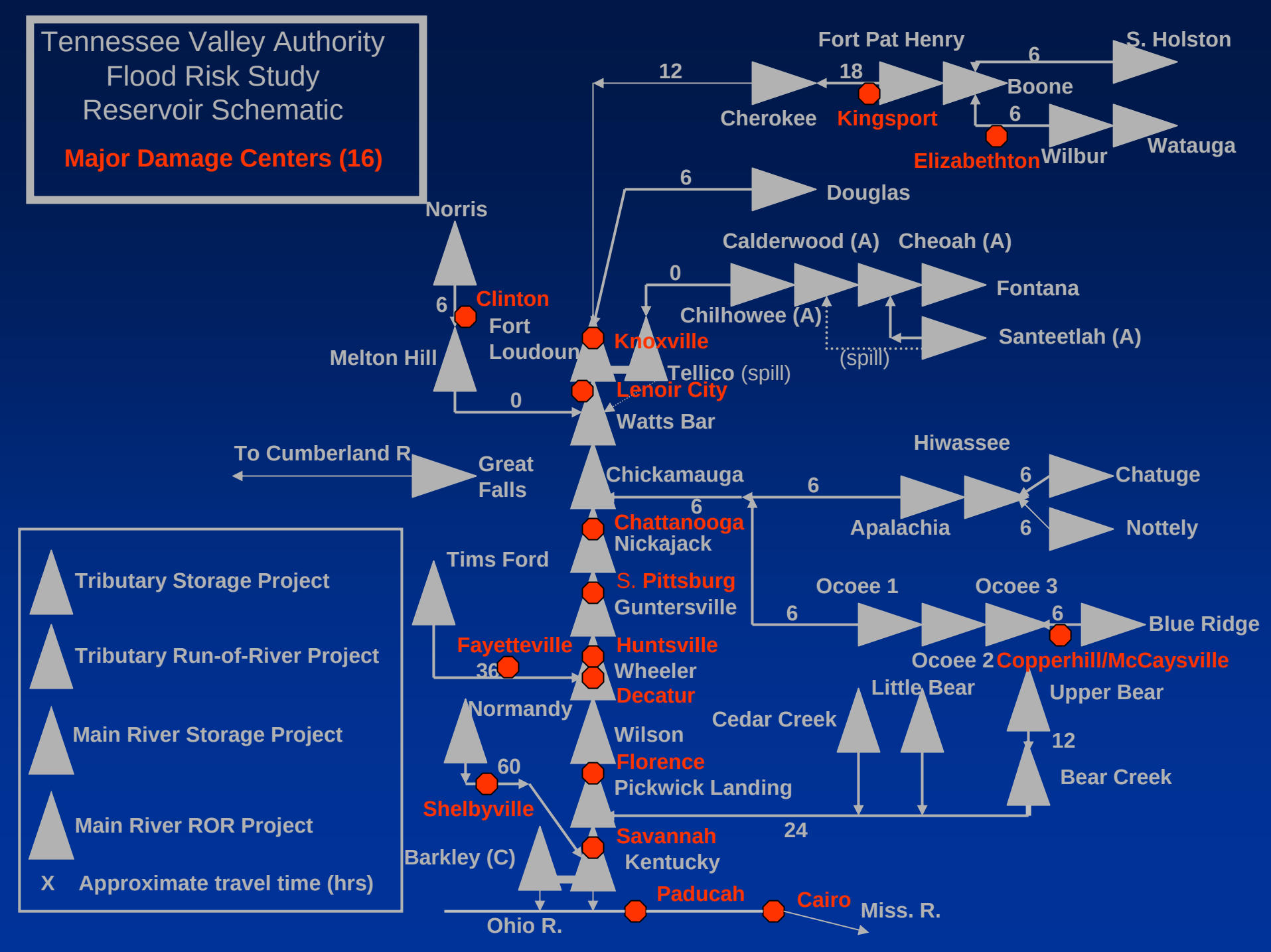
Main River - Multipurpose
Guntersville

Tributary - Run-of-River Power
Apalachia

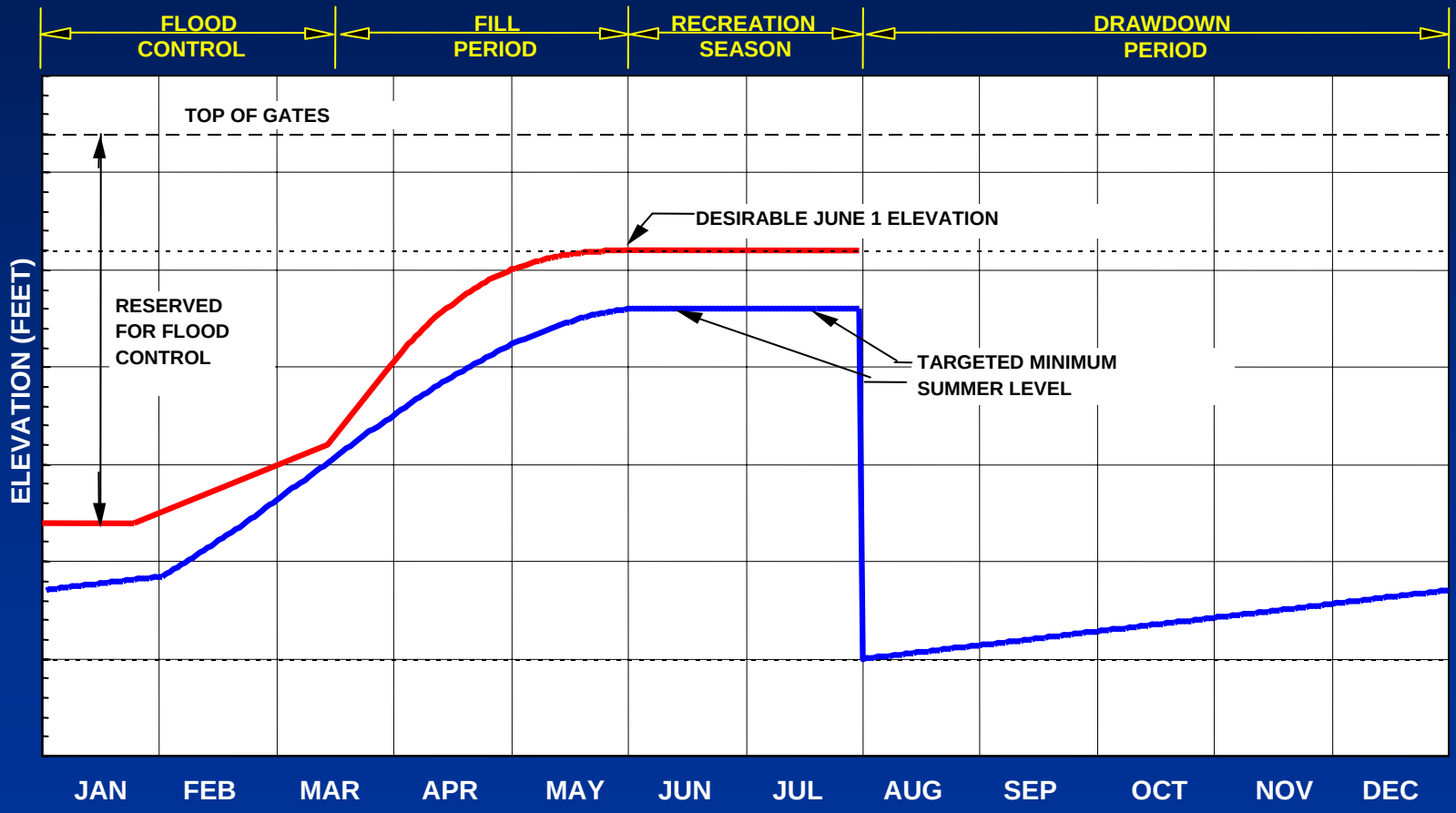
Tributary - Nonpower
Little Bear Creek

Tennessee Valley Authority
Reservoir Operations Study

1. Determine if revised reservoir system operating policies could create greater overall public value
2. Consider public input
3. Quantify trade-offs
4. Don’t increase flood risk


Tennessee Valley Authority
Flood Risk Study
Reservoir Schematic
Major Damage Centers (16)
Fort Pat Henry
S. Holston
12
18
6
Boone
Cherokee
Kingsport
6
Elizabethton
Wilbur
Watauga
6
Douglas
Norris
Calderwood (A)
Cheoah (A)
0
Fontana
6
Clinton
Fort Loudoun
Chilhowee (A)
Santeetlah (A)
Melton Hill
Knoxville
(spill)
Tellico (spill)
Lenoir City
0
Watts Bar
To Cumberland R
Great Falls
Hiwassee
Chickamauga
6
6
6
Chatuge
Chattanooga
Nickajack
Apalachia
6
Nottely
Tims Ford
S. Pittsburg
Guntersville
Ocoee 1
Ocoee 3
6
6
Blue Ridge
Fayetteville
Huntsville
Wheeler
Decatur
36
Ocoee 2
Copperhill/McCaysville
Little Bear
Upper Bear
Normandy
Cedar Creek
Wilson
12
Florence
60
Pickwick Landing
Bear Creek
Shelbyville
24
Savannah
Barkley (C)
Kentucky
Paducah
Cairo
Miss. R.
Ohio R.
Tributary Storage Project
Tributary Run-of-River Project
Main River Storage Project
Main River ROR Project
X Approximate travel time (hrs)

Typical Guide Curve



TVA Data

- Use USGS streamflow data for 99-year period
- 6-hour time step
- Required extensive data filling and disaggregation in time
- Data stored in ASCII flat-files

TVA Modeling

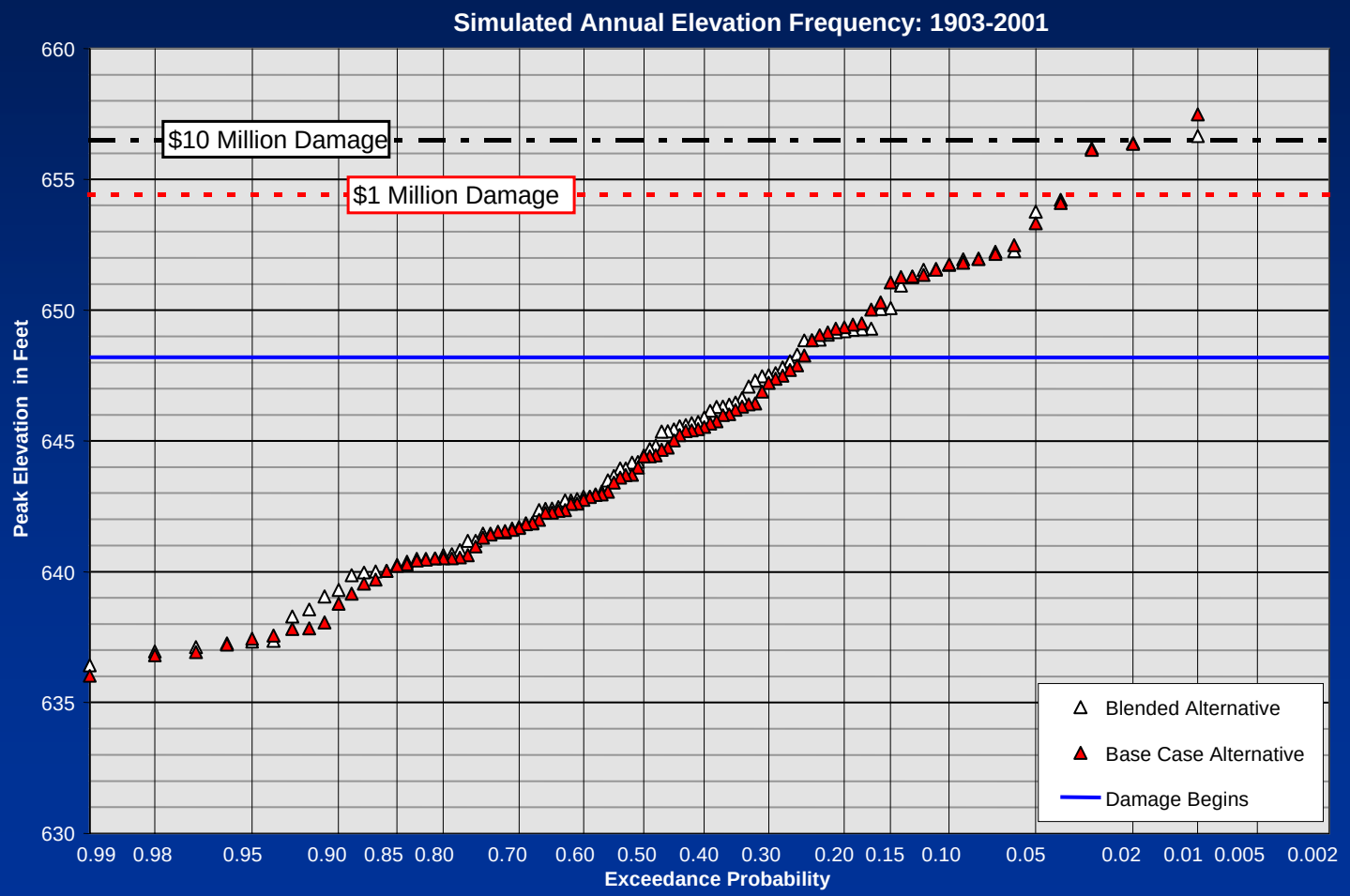
- RiverWare^{tm} from U. of Colorado
- Modeled 36 of the most important reservoirs
- Segmentation in space and time
- DMIs to control simulation runs
- Calibrated to historical operations 1990-2003

TVA Modeling (cont)

- Development of rule sets for current operations
- Make modifications to rules for scenarios
- Graphical products for comparison of results

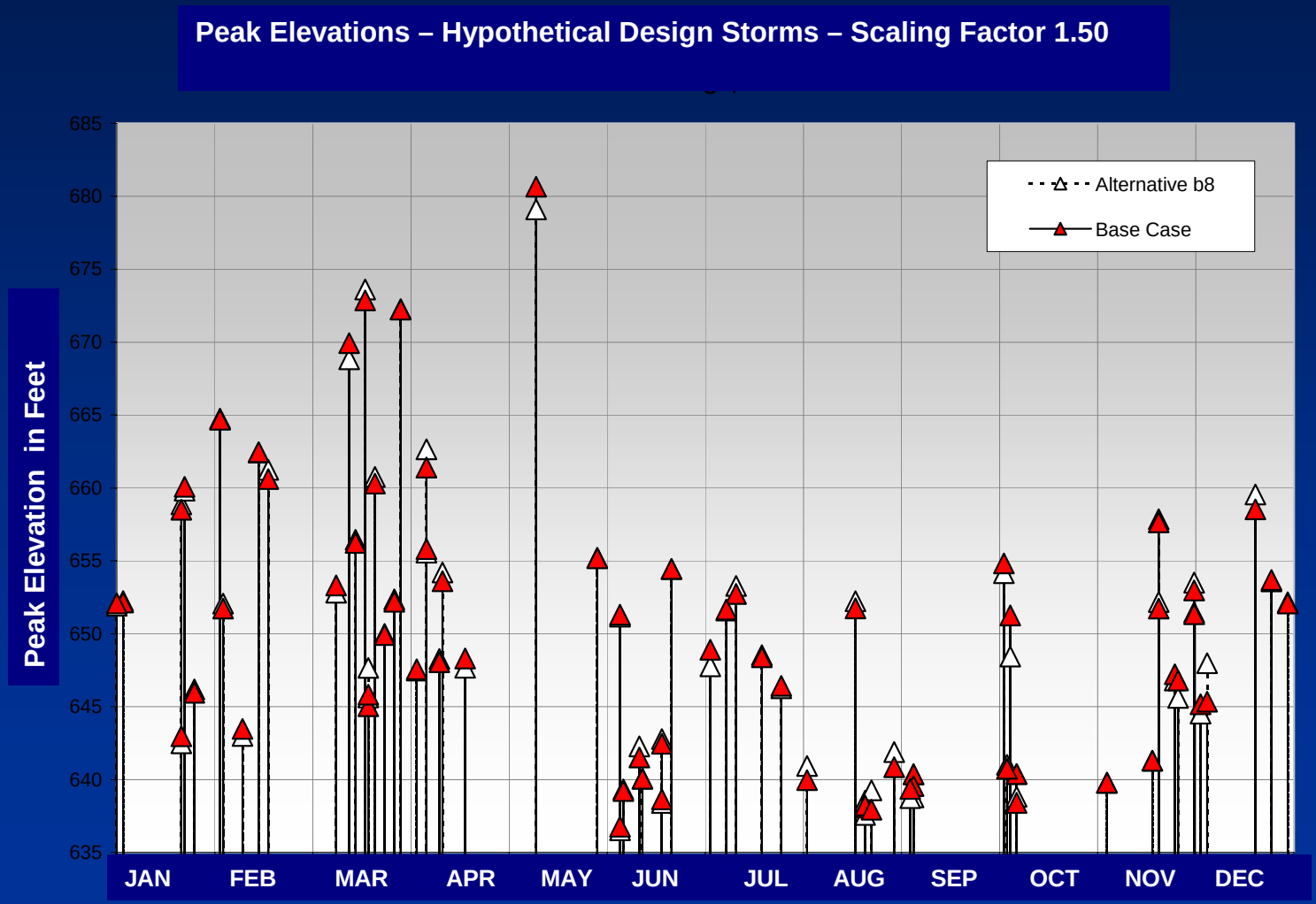
Comparison of Results

Frequency Plots



Comparison of Results

Scaled Design Storms



TVA System Results

- Revised operating policies that provide:
  - Lower cost of transportation
  - Increased reliability of power
  - Increased recreational opportunities
  - Enhanced wildlife habitat
  - Improved water quality

…without increasing flood risk

Colorado River Basin

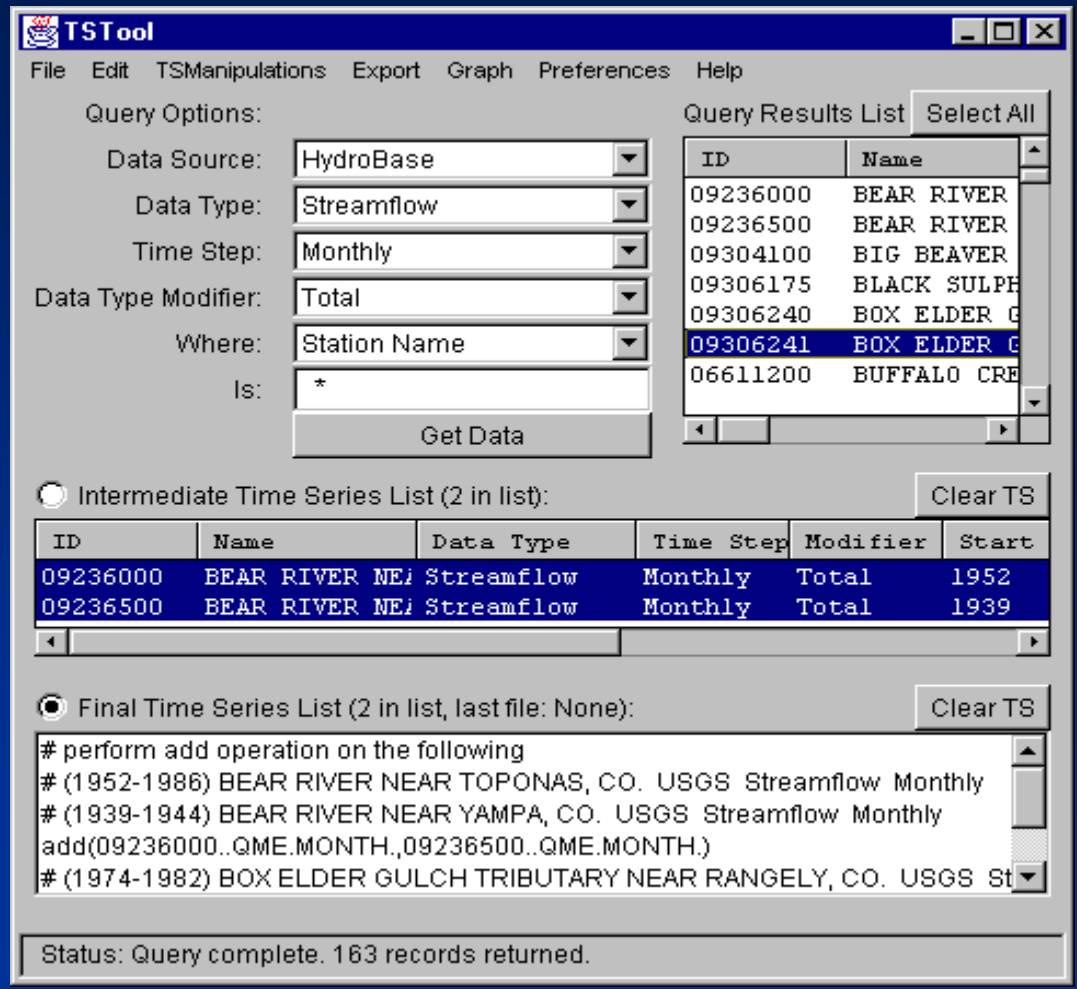
- Approx. 20,000 water rights managed on Prior Appropriation System
- Management subject to interstate and international compacts
- Headwater in Colorado

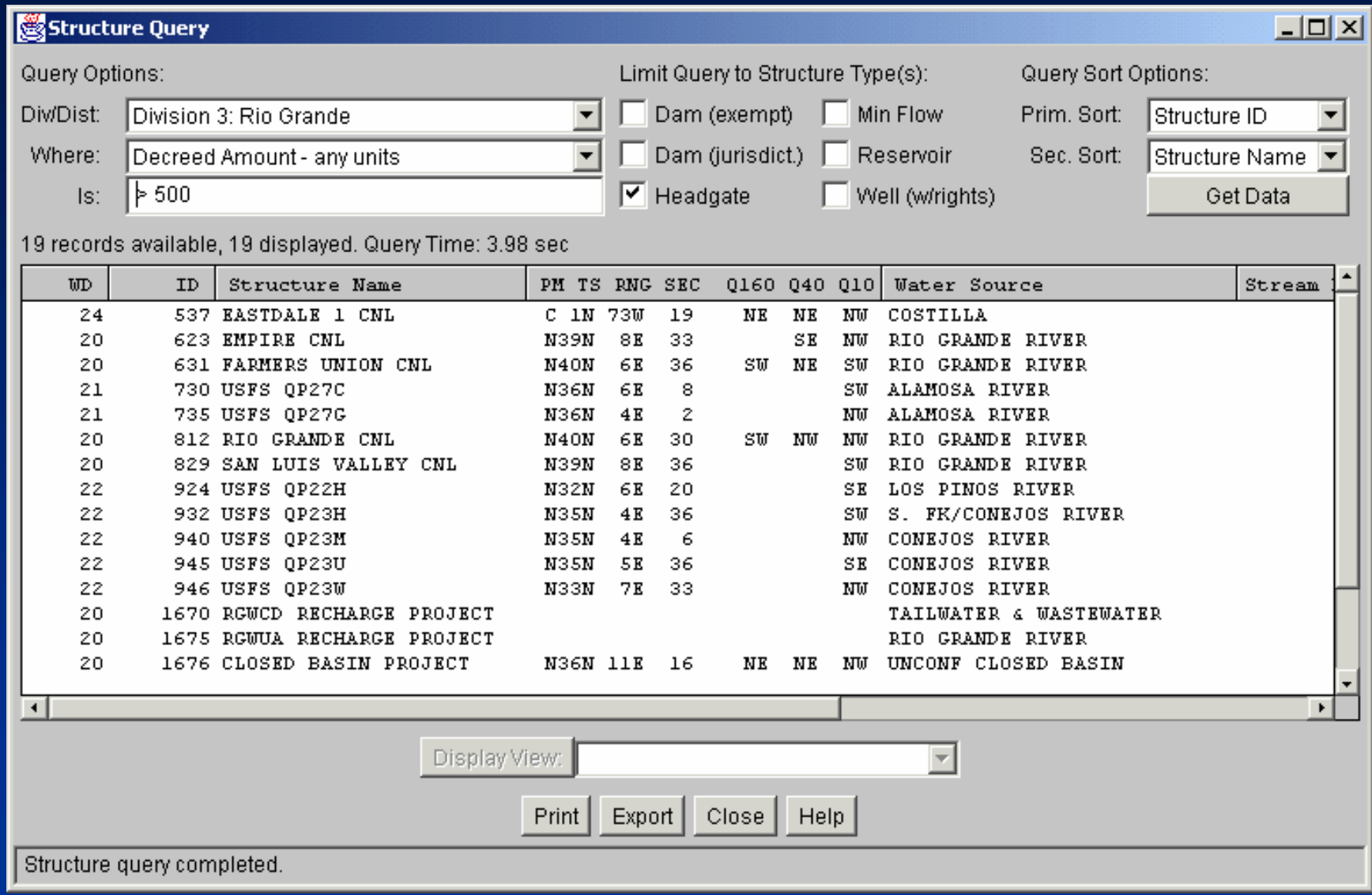
CDSS

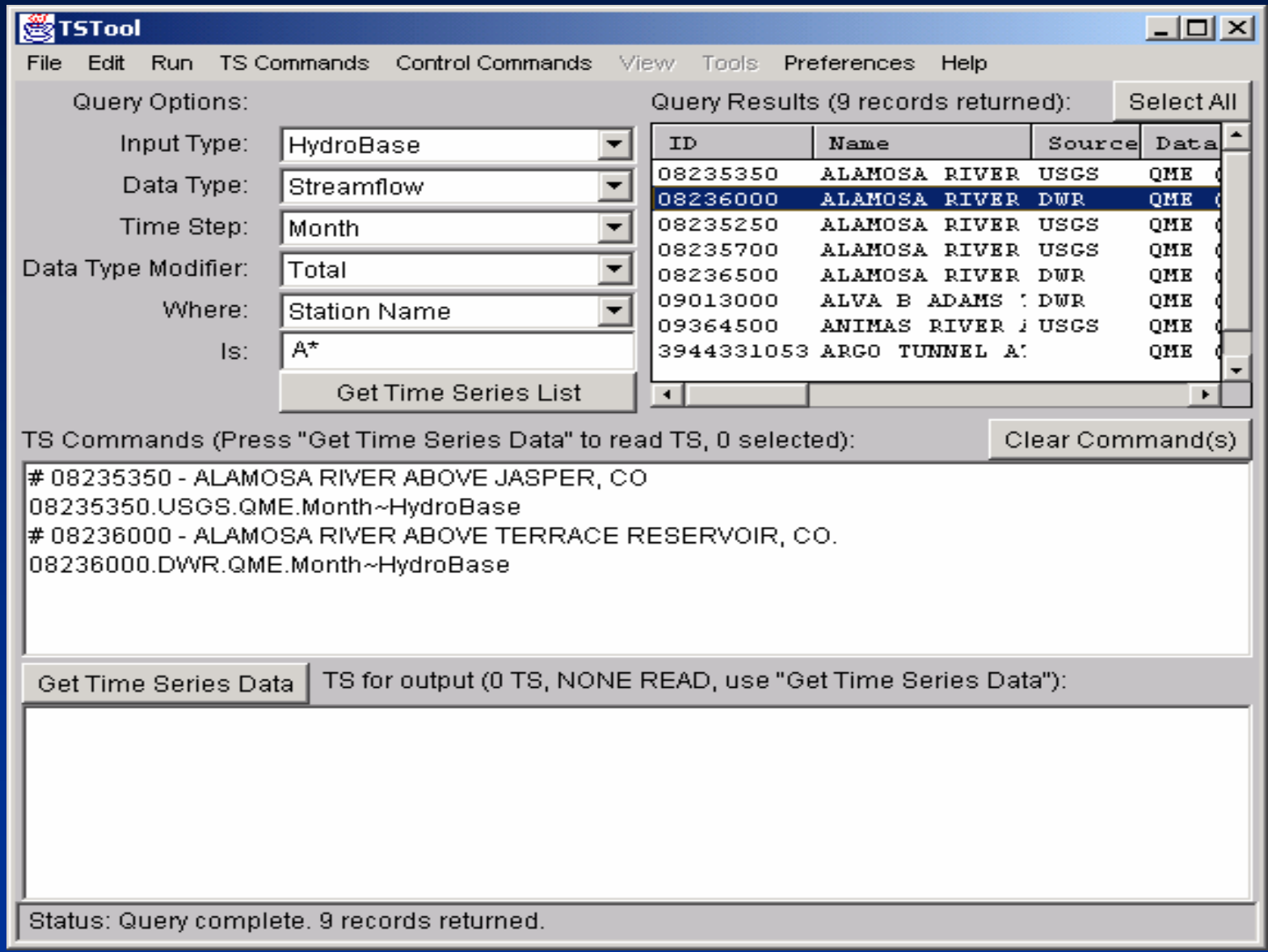
Colorado's Decision Support System

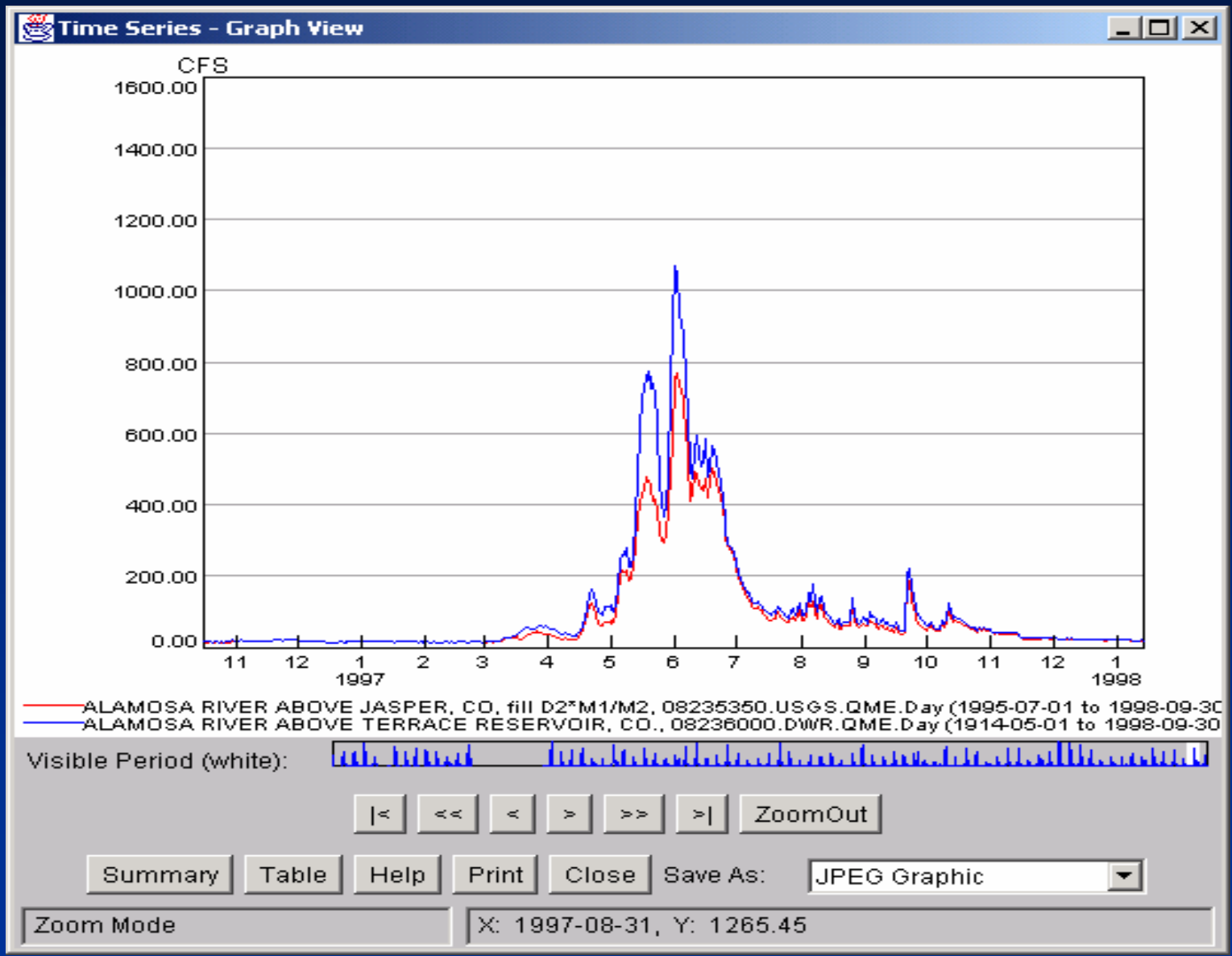
Planning Models - View/Analyze Data

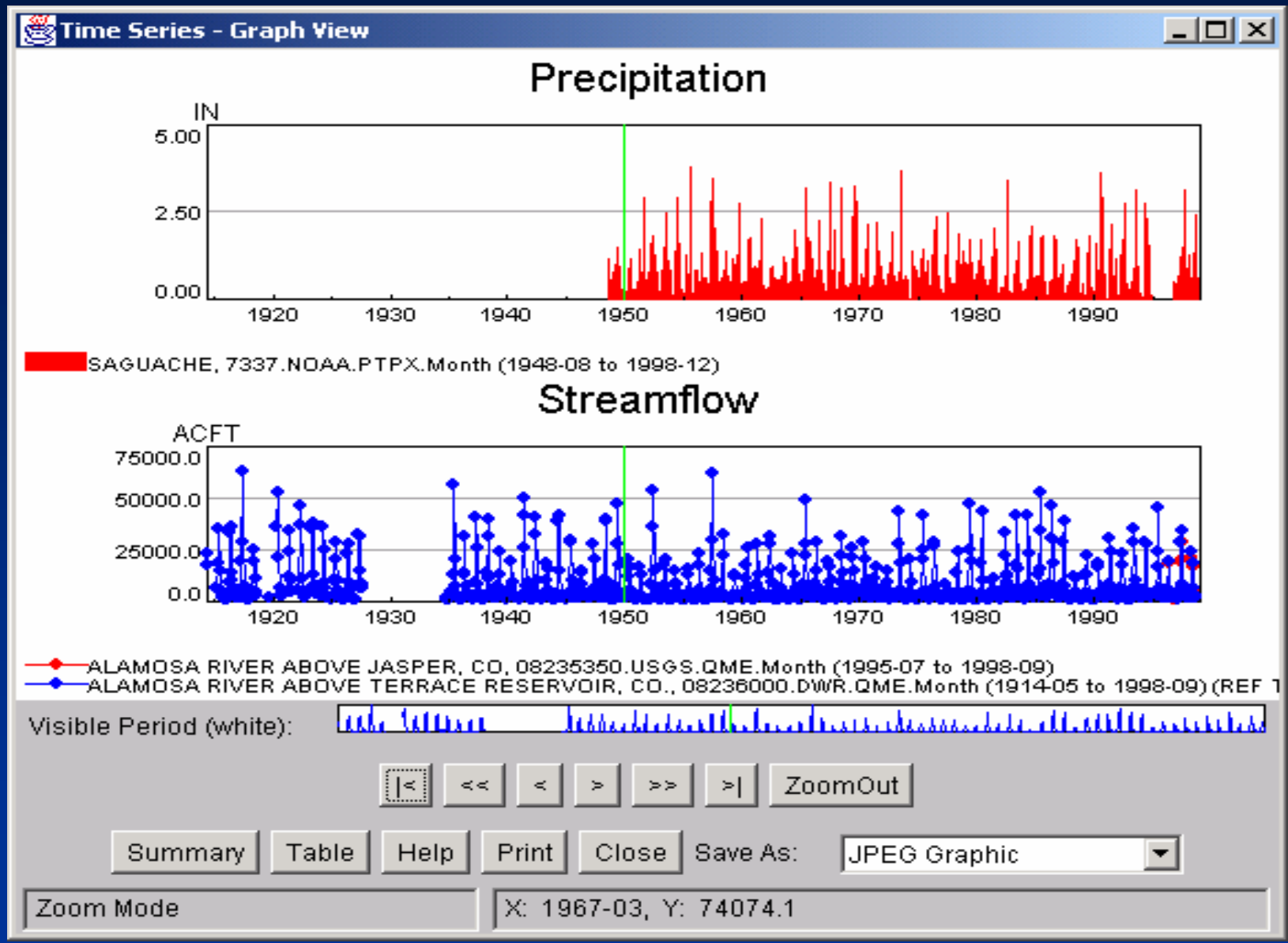
- Data views
- Reports
- TSTool for analysis
- StateMod/GUI and utilities
- Share data

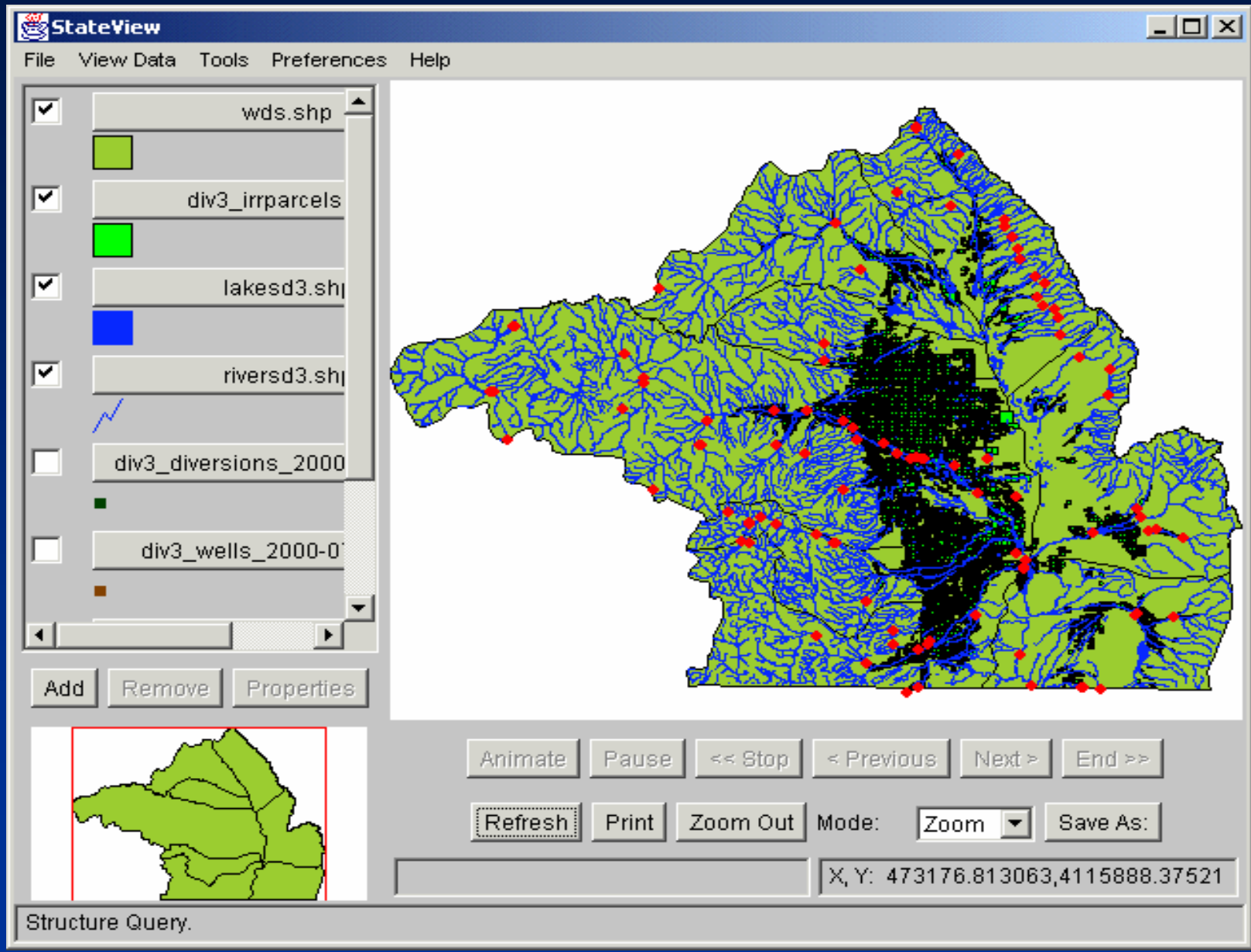



Structure Query
Query Options:
Div/Dist:
Division 3: Rio Grande
Where:
Decreed Amount - any units
Is:
> 500
Limit Query to Structure Type(s):
Dam (exempt)
Dam (jurisdict.)
Headgate
Min Flow
Reservoir
Well (w/rights)
Query Sort Options:
Prim. Sort:
Structure ID
Sec. Sort:
Structure Name
Get Data
19 records available, 19 displayed. Query Time: 3.98 sec
WD ID Structure Name PM TS RNG SEC Q160 Q40 Q10 Water Source Stream
24 537 EASTDALE 1 CNL C 1N 73W 19 NE NE NW COSTILLA
20 623 EMPIRE CNL N39N 8E 33 SE NW RIO GRANDE RIVER
20 631 FARMERS UNION CNL N40N 6E 36 SW NE SW RIO GRANDE RIVER
21 730 USFS QP27C N36N 6E 8 SW ALAMOSA RIVER
21 735 USFS QP27G N36N 4E 2 NW ALAMOSA RIVER
20 812 RIO GRANDE CNL N40N 6E 30 SW NW NW RIO GRANDE RIVER
20 829 SAN LUIS VALLEY CNL N39N 8E 36 SW RIO GRANDE RIVER
22 924 USFS QP22H N32N 6E 20 SE LOS PINOS RIVER
22 932 USFS QP23H N35N 4E 36 SW S. FK/CONEJOS RIVER
22 940 USFS QP23M N35N 4E 6 NW CONEJOS RIVER
22 945 USFS QP23U N35N 5E 36 SE CONEJOS RIVER
22 946 USFS QP23W N33N 7E 33 NW CONEJOS RIVER
20 1670 RGWCD RECHARGE PROJECT TAILWATER & WASTEWATER
20 1675 RGWUA RECHARGE PROJECT RIO GRANDE RIVER
20 1676 CLOSED BASIN PROJECT N36N 11E 16 NE NE NW UNCONF CLOSED BASIN
Display View:
Print
Export
Close
Help
Structure query completed.


TSTool
File Edit Run TS Commands Control Commands View Tools Preferences Help
Query Options:
Input Type: HydroBase
Data Type: Streamflow
Time Step: Month
Data Type Modifier: Total
Where: Station Name
Is: A*
Get Time Series List
Query Results (9 records returned):
Select All
ID Name Source Data
08235350 ALAMOSA RIVER USGS QME
08236000 ALAMOSA RIVER DWR QME
08235250 ALAMOSA RIVER USGS QME
08235700 ALAMOSA RIVER USGS QME
08236500 ALAMOSA RIVER DWR QME
09013000 ALVA B ADAMS DWR QME
09364500 ANIMAS RIVER USGS QME
3944331053 ARGO TUNNEL QME
TS Commands (Press "Get Time Series Data" to read TS, 0 selected):
Clear Command(s)
08235350 - ALAMOSA RIVER ABOVE JASPER, CO
08235350.USGS.QME.Month~HydroBase
08236000 - ALAMOSA RIVER ABOVE TERRACE RESERVOIR, CO.
08236000.DWR.QME.Month~HydroBase
Get Time Series Data
TS for output (0 TS, NONE READ, use "Get Time Series Data"):
Status: Query complete. 9 records returned.


Time Series - Graph View
CFS
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
11
12
1
1997
2
3
4
5
6
7
8
9
10
11
12
1
1998
ALAMOSA RIVER ABOVE JASPER, CO, fill D2*M1/M2, 08235350.USGS.QME.Day (1995-07-01 to 1998-09-30
ALAMOSA RIVER ABOVE TERRACE RESERVOIR, CO., 08236000.DWR.QME.Day (1914-05-01 to 1998-09-30
Visible Period (white):
|<
<<
<
>
>>
>|
ZoomOut
Summary
Table
Help
Print
Close
Save As:
JPEG Graphic
Zoom Mode
X: 1997-08-31, Y: 1265.45

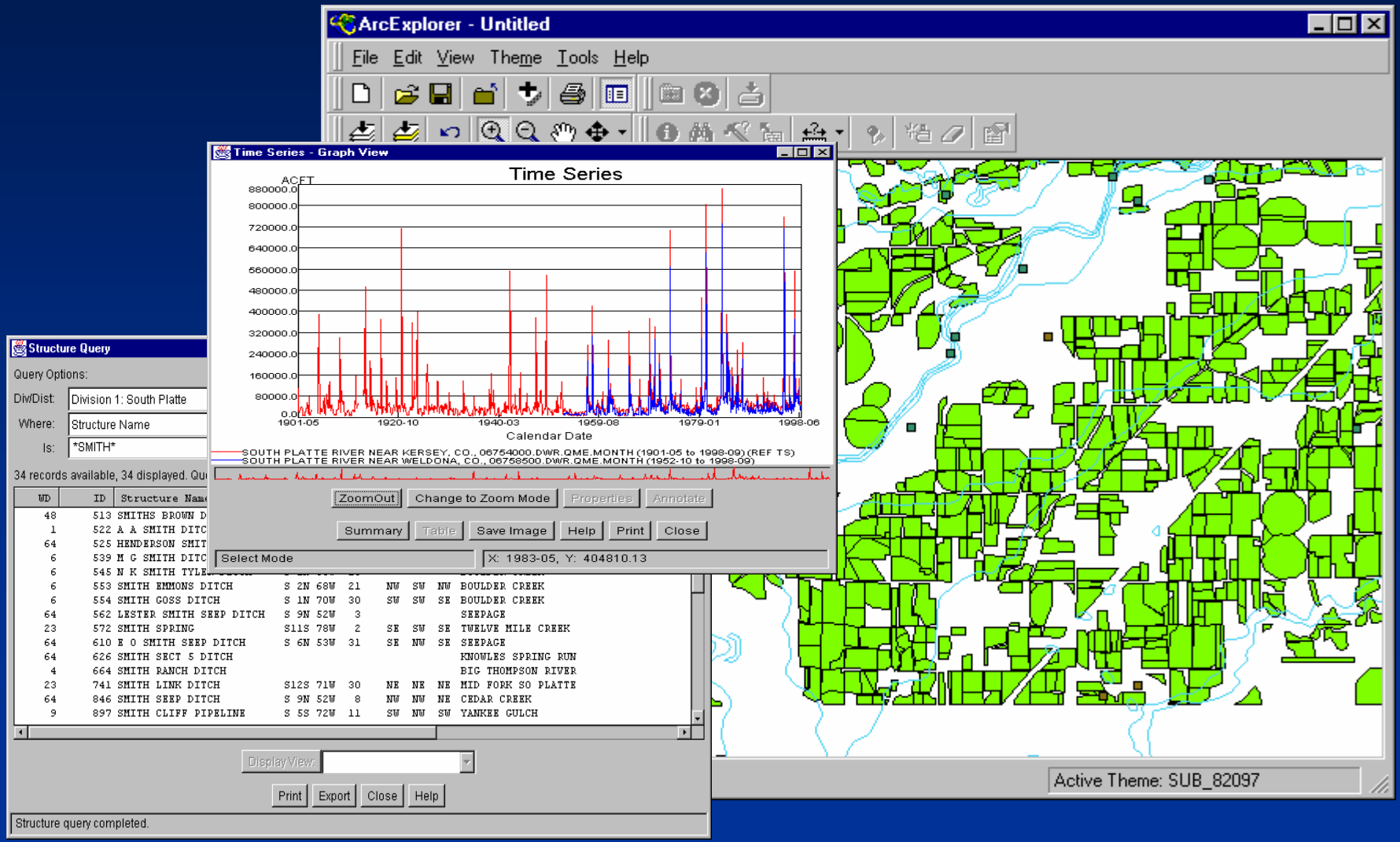

Time Series - Graph View
Precipitation
IN
5.00
2.50
0.00
1920
1930
1940
1950
1960
1970
1980
1990
SAGUACHE, 7337.NOAA.PTPX.Month (1948-08 to 1998-12)
Streamflow
ACFT
75000.0
50000.0
25000.0
0.0
1920
1930
1940
1950
1960
1970
1980
1990
ALAMOSA RIVER ABOVE JASPER, CO, 08235350.USGS.QME.Month (1995-07 to 1998-09)
ALAMOSA RIVER ABOVE TERRACE RESERVOIR, CO., 08236000.DWR.QME.Month (1914-05 to 1998-09) (REF
Visible Period (white):
|<
<<
<
>
>>
>|
ZoomOut
Summary
Table
Help
Print
Close
Save As:
JPEG Graphic
Zoom Mode
X: 1967-03, Y: 74074.1


StateView
File
View Data
Tools
Preferences
Help
wds.shp
div3_irrparcels
lakesd3.shp
riversd3.shp
div3_diversions_2000
div3_wells_2000-0
Add
Remove
Properties
Animate
Pause
<< Stop
< Previous
Next >
End >>
Refresh
Print
Zoom Out
Mode:
Zoom
Save As:
X, Y: 473176.813063,4115888.37521
Structure Query.

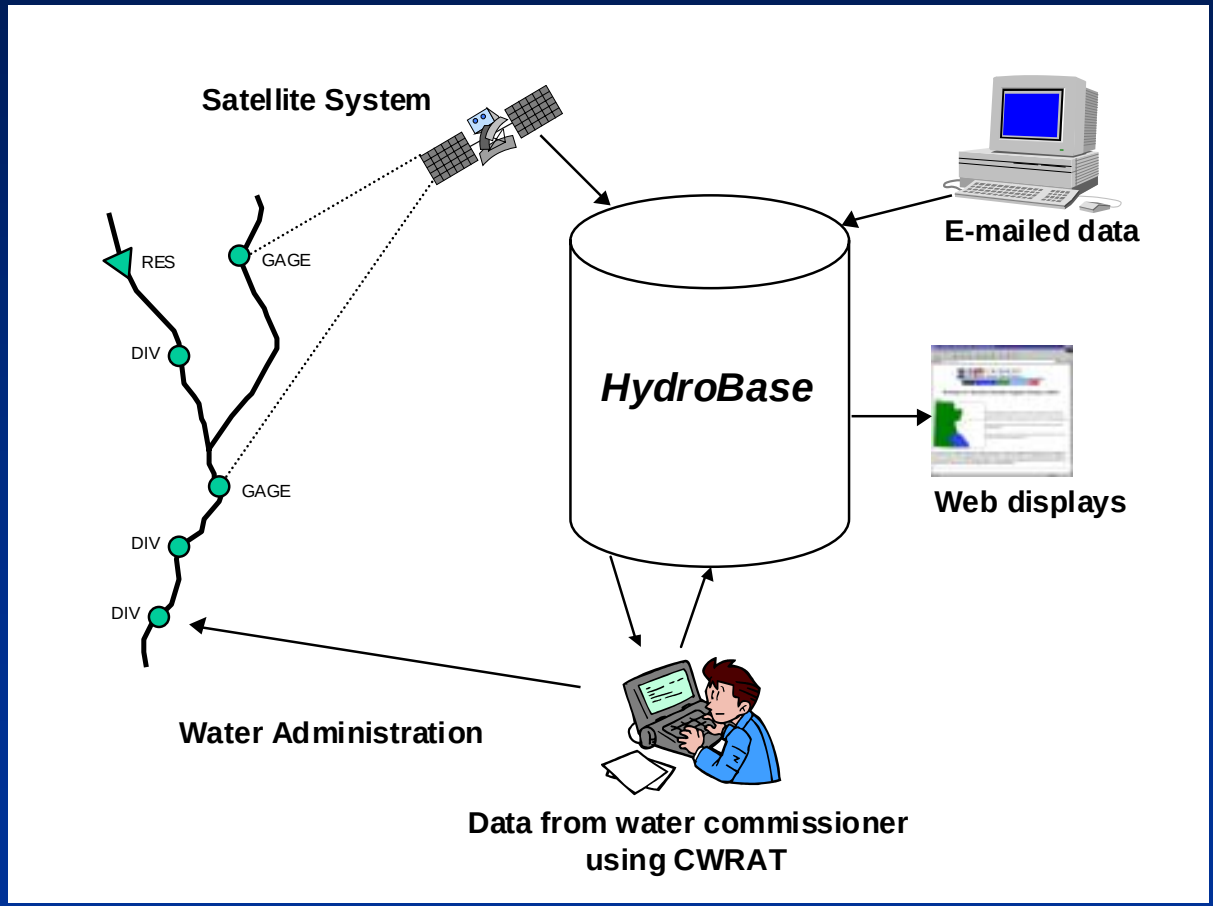
StateMod Planning Model

- Network model
- Monthly or daily time step
- Demands for diversions, instream flow, reservoirs, wells
- Operational rights used to model relationships between structures
- Allocation based on water rights
- Database utilities automate the creation of model files

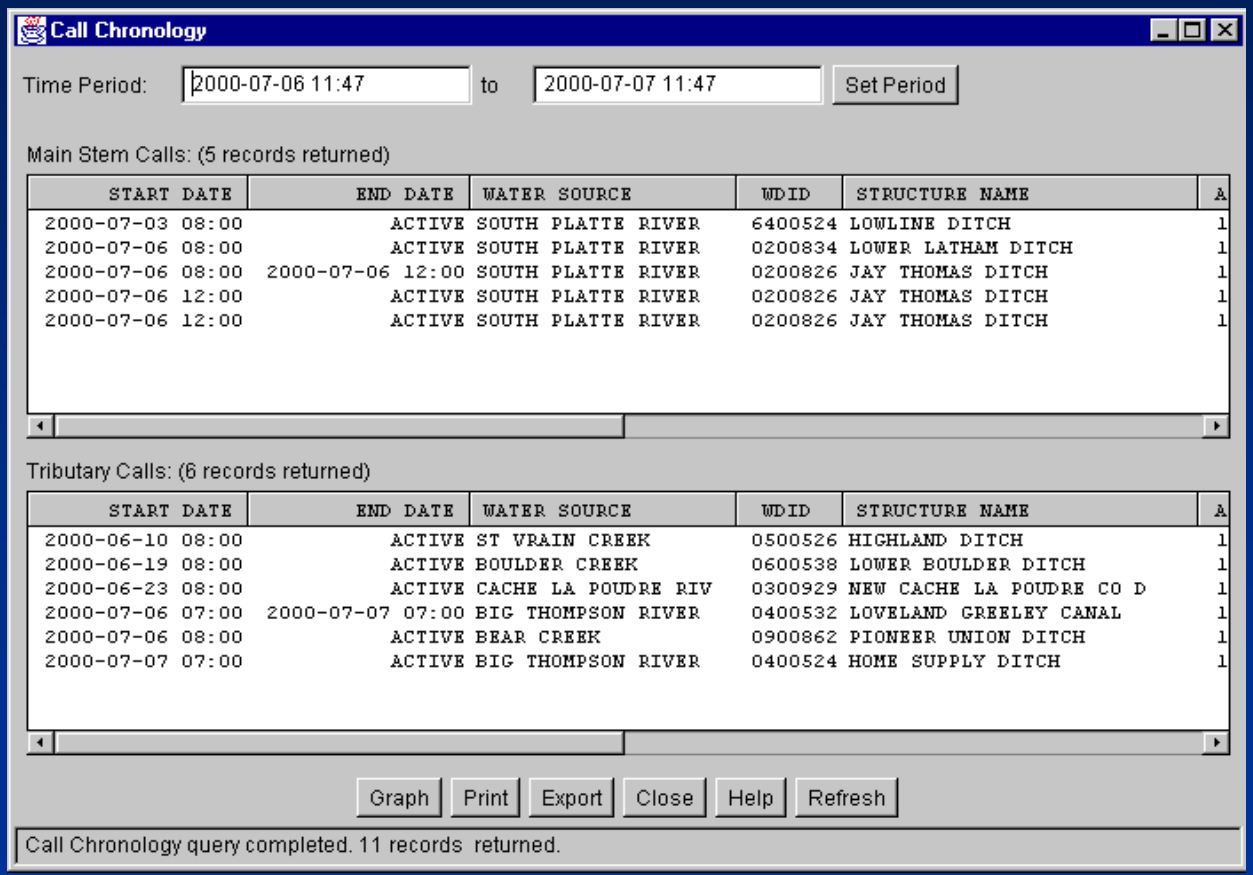
Estimation of CU from Irrigated Acreage



Water Administration using CWRAT

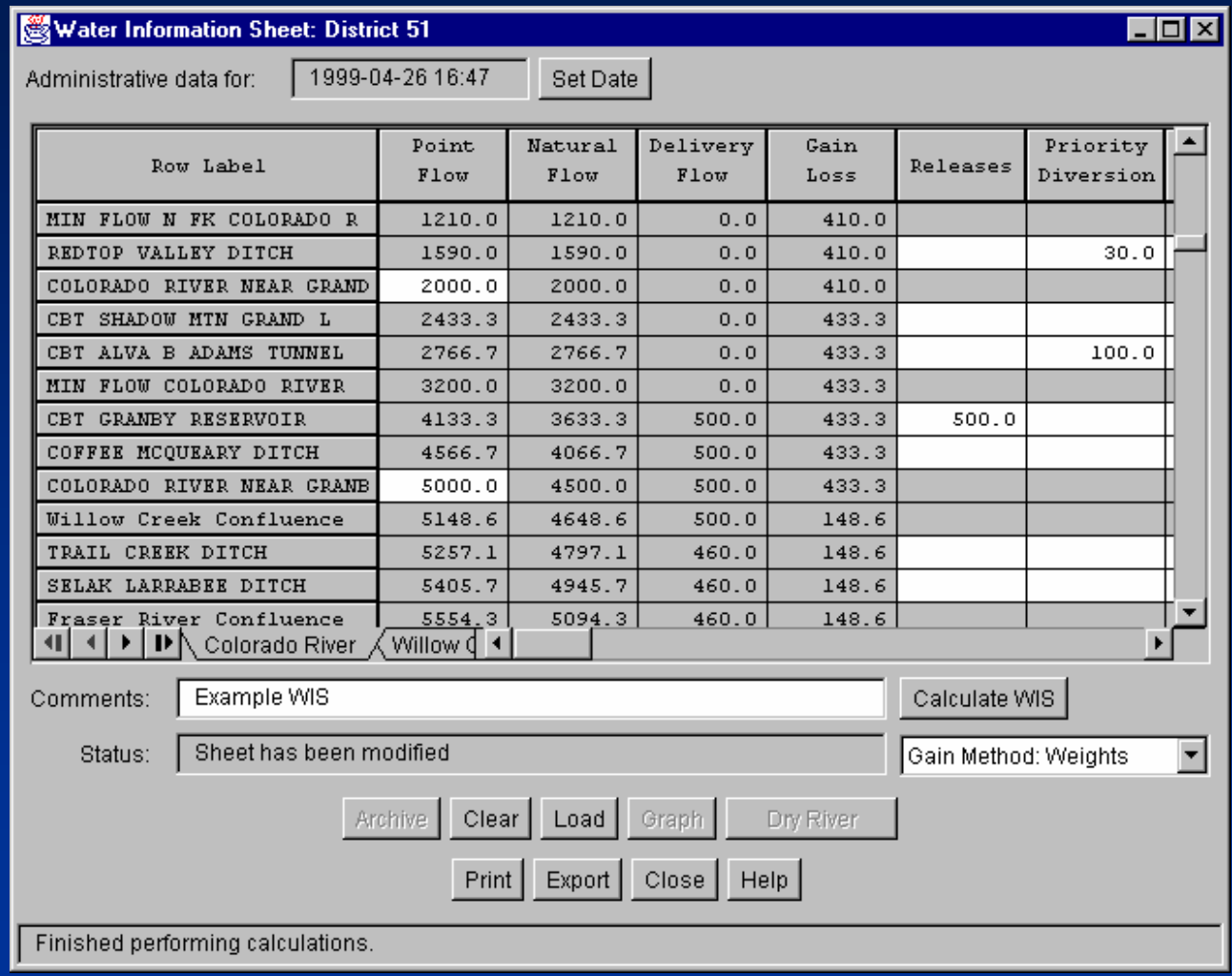


CWRAT - Calls

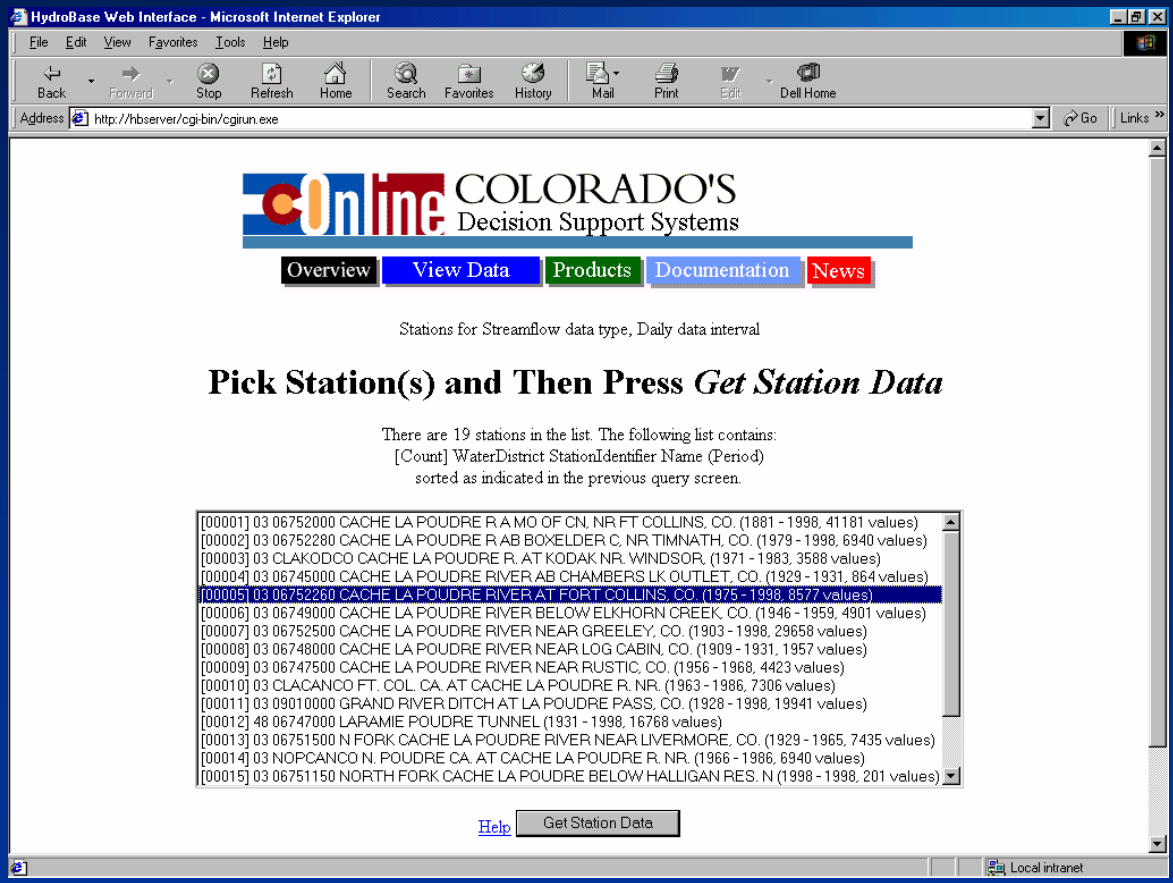

Call Chronology
Time Period: 2000-07-06 11:47 to 2000-07-07 11:47 Set Period
Main Stem Calls: (5 records returned)
START DATE | END DATE | WATER SOURCE | WDID | STRUCTURE NAME | A
2000-07-03 08:00 | ACTIVE | SOUTH PLATTE RIVER | 6400524 | LOWLINE DITCH | 1
2000-07-06 08:00 | ACTIVE | SOUTH PLATTE RIVER | 0200834 | LOWER LATHAM DITCH | 1
2000-07-06 08:00 | 2000-07-06 12:00 | SOUTH PLATTE RIVER | 0200826 | JAY THOMAS DITCH | 1
2000-07-06 12:00 | ACTIVE | SOUTH PLATTE RIVER | 0200826 | JAY THOMAS DITCH | 1
2000-07-06 12:00 | ACTIVE | SOUTH PLATTE RIVER | 0200826 | JAY THOMAS DITCH | 1
Tributary Calls: (6 records returned)
START DATE | END DATE | WATER SOURCE | WDID | STRUCTURE NAME | A
2000-06-10 08:00 | ACTIVE | ST VRAIN CREEK | 0500526 | HIGHLAND DITCH | 1
2000-06-19 08:00 | ACTIVE | BOULDER CREEK | 0600538 | LOWER BOULDER DITCH | 1
2000-06-23 08:00 | ACTIVE | CACHE LA POUDRE RIV | 0300929 | NEW CACHE LA POUDRE CO D | 1
2000-07-06 07:00 | 2000-07-07 07:00 | BIG THOMPSON RIVER | 0400532 | LOVELAND GREELEY CANAL | 1
2000-07-06 08:00 | ACTIVE | BEAR CREEK | 0900862 | PIONEER UNION DITCH | 1
2000-07-07 07:00 | ACTIVE | BIG THOMPSON RIVER | 0400524 | HOME SUPPLY DITCH | 1
Graph Print Export Close Help Refresh
Call Chronology query completed. 11 records returned.

Administration - Water Information Sheets

- More than water balance
- Analysis potential
- Simplifies data entry
- Import data
- Graph decisions

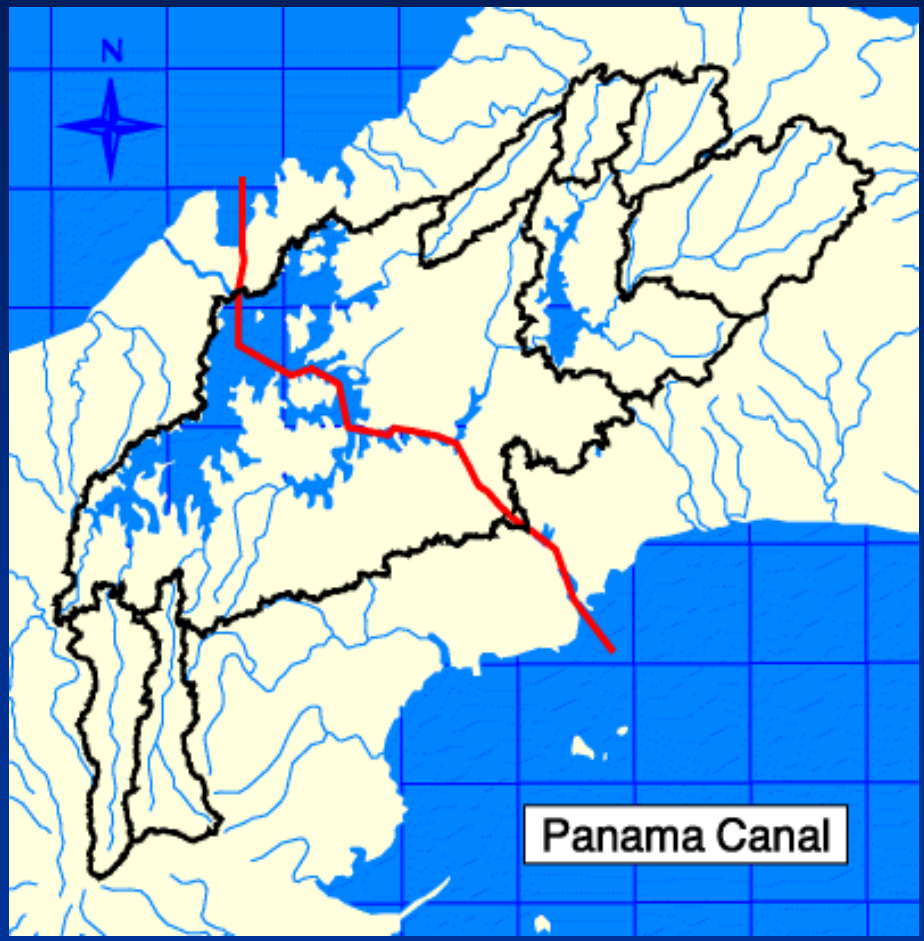


CDSS Web Interface



- Product distribution
- Tabular data query
- Graphical data query
- Data sharing
- Documentation

Forecast Model Example - Panama



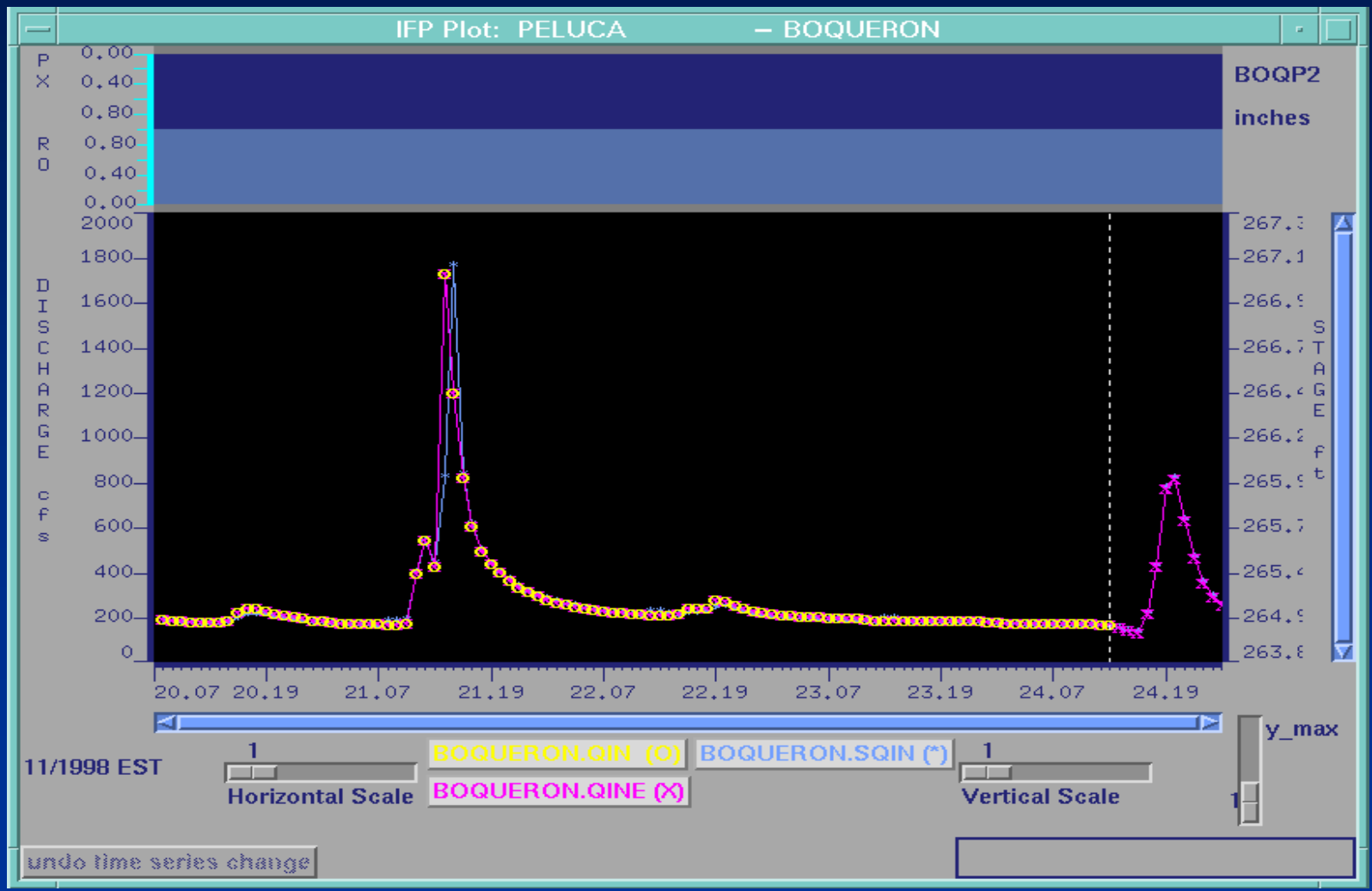
Panama Canal - Data

- Real-time inputs of precipitation, streamflow, and reservoir levels
- Data collected 15-minutes to hourly
- Precipitation forecasts for next 12 to 24 hours

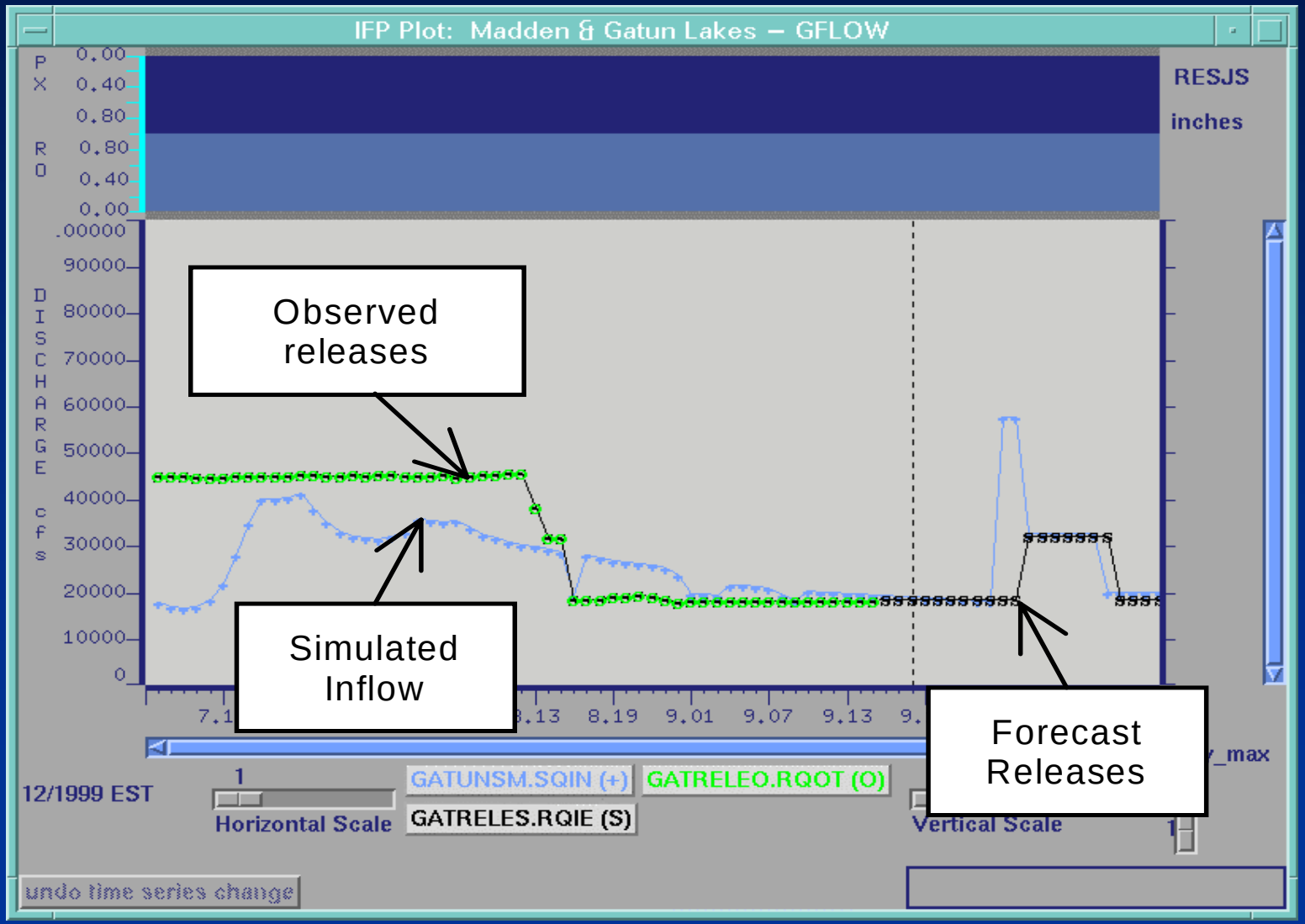
Panama Canal - Modeling

- NWS River Forecast System
  - Sacramento Soil Moisture Accounting Model
  - Joint Reservoir Operations Model
- 1-hour time step - areal averaged precipitation
- User can modify inputs in real-time

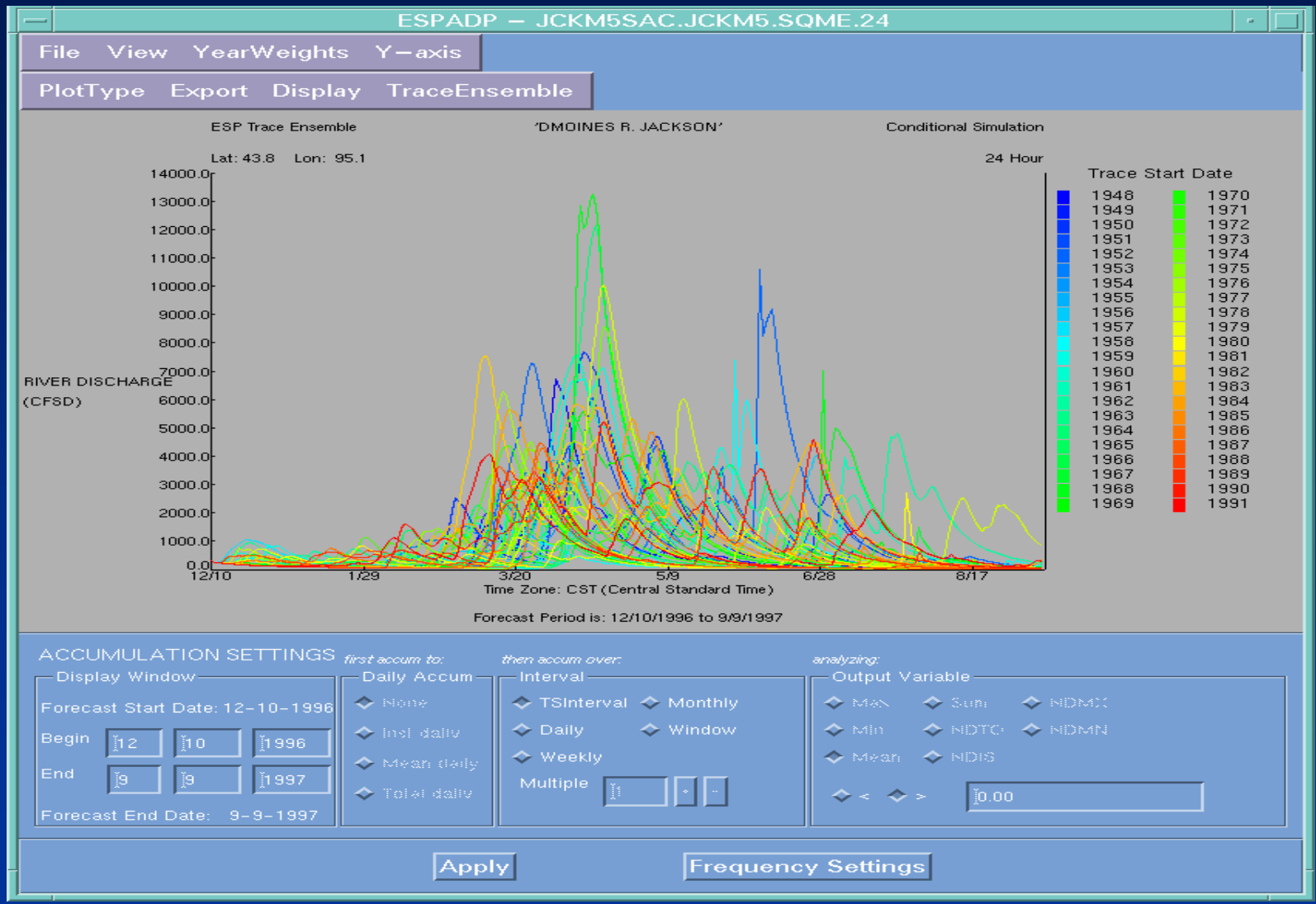
Short-term Forecasting - Flow



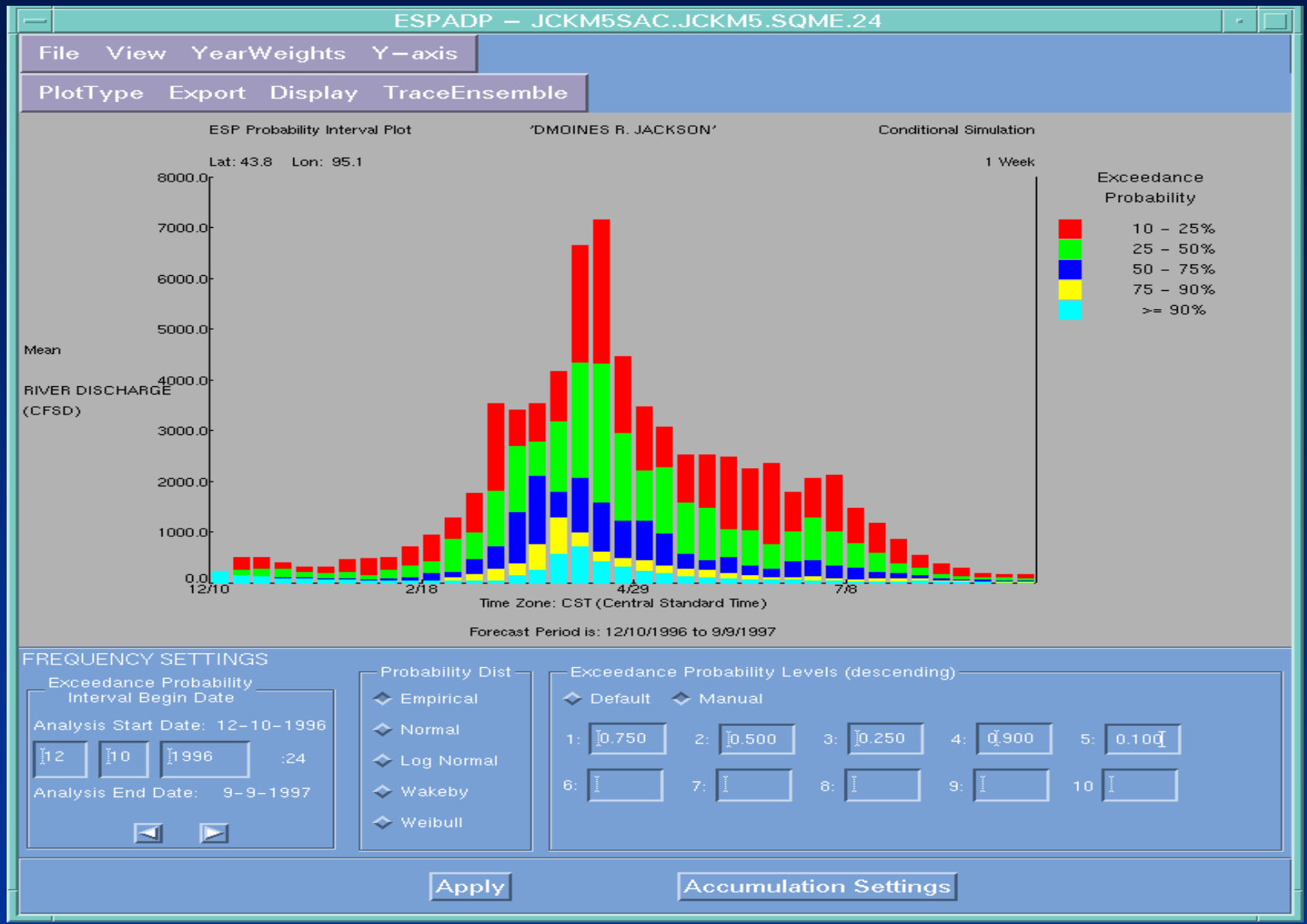
Short-term Forecasting – Reservoir Operations



Long-Term Forecasting - ESP

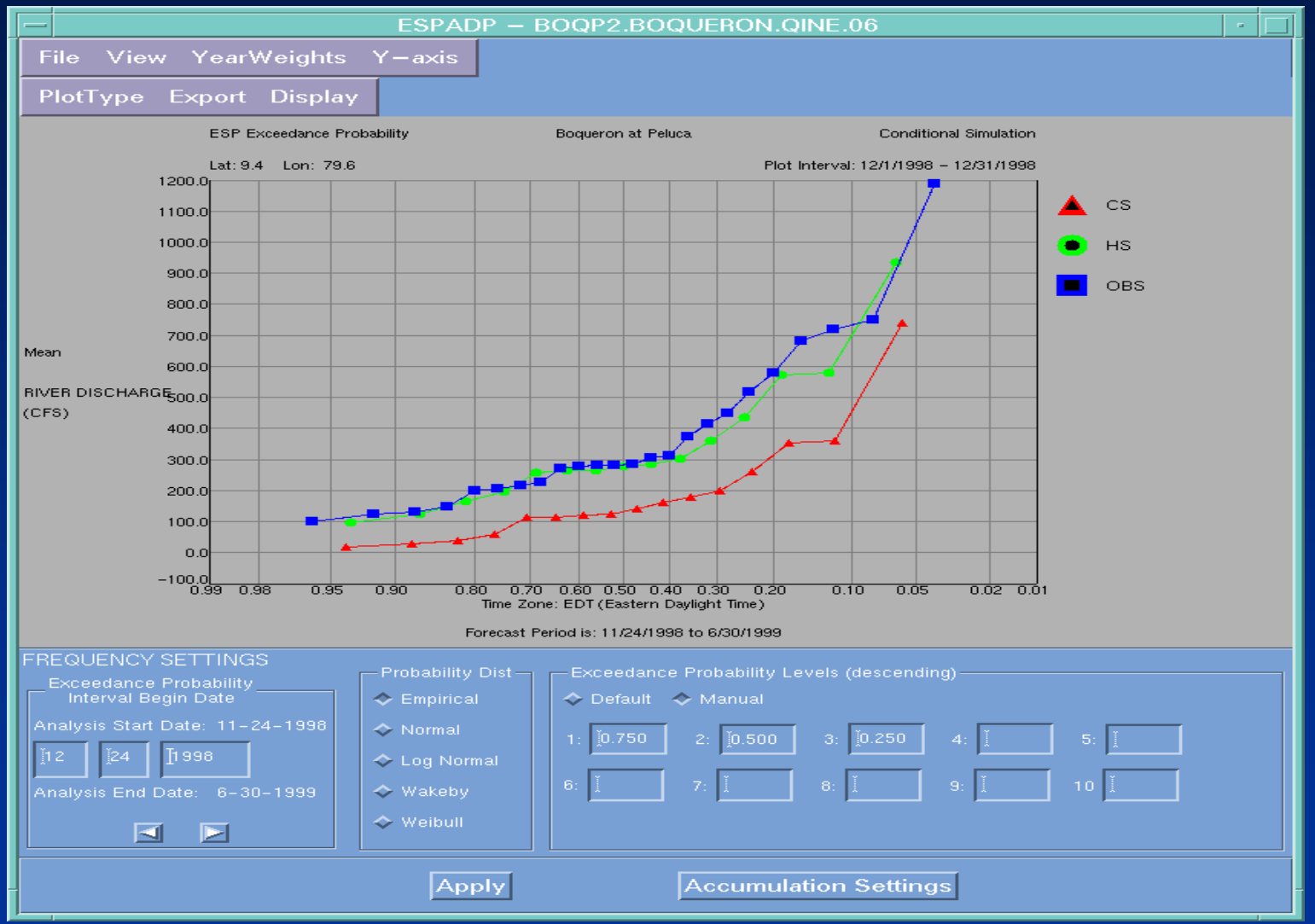


Long-Term Forecasting - ESP



Probability Histogram

Long-Term Forecasting - ESP



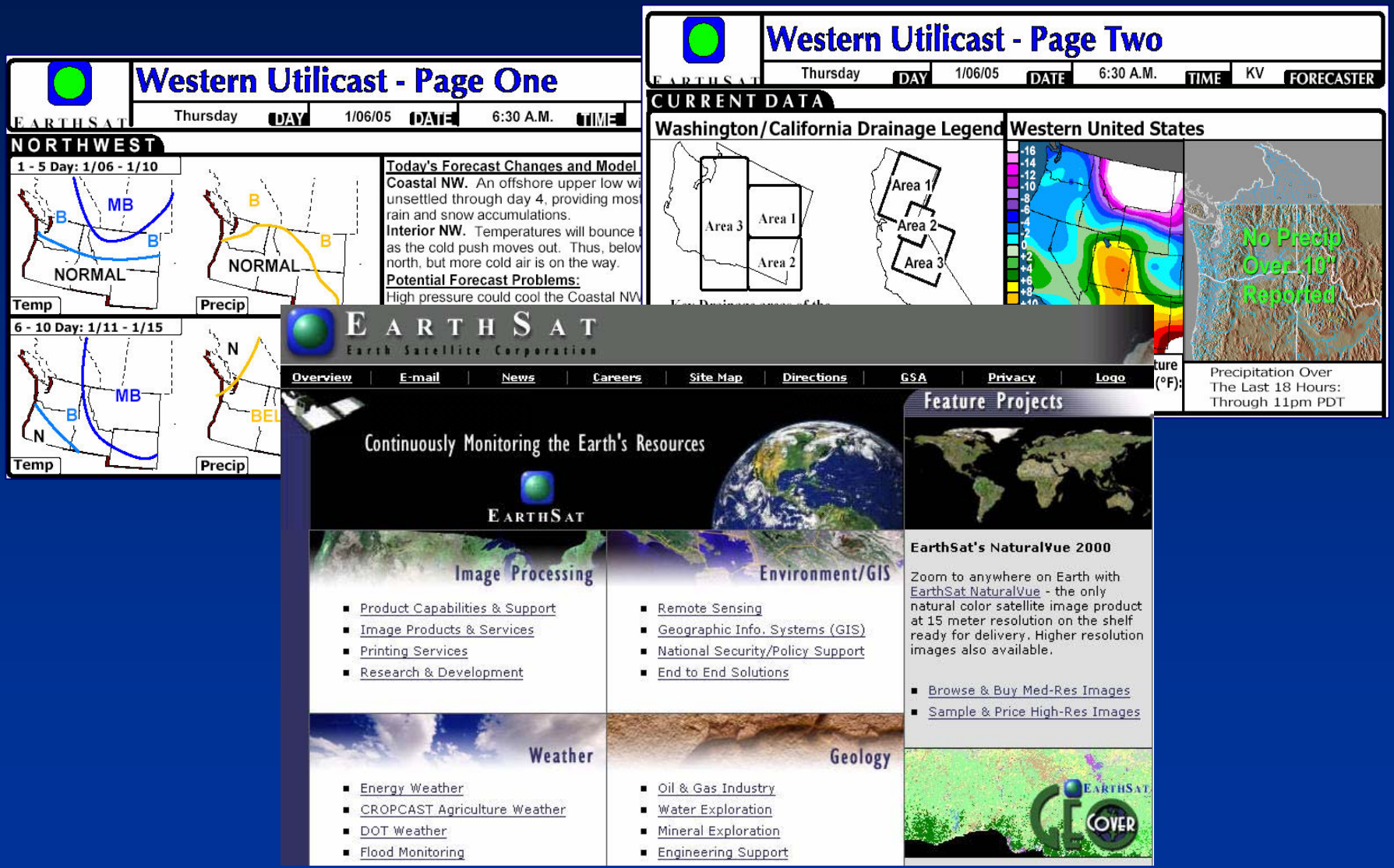
Exceedance Probability

ESP Issues

- Historical climate may not be representative of future events
- Short-term climate forecast skill is improving and should be accounted for
- Verification

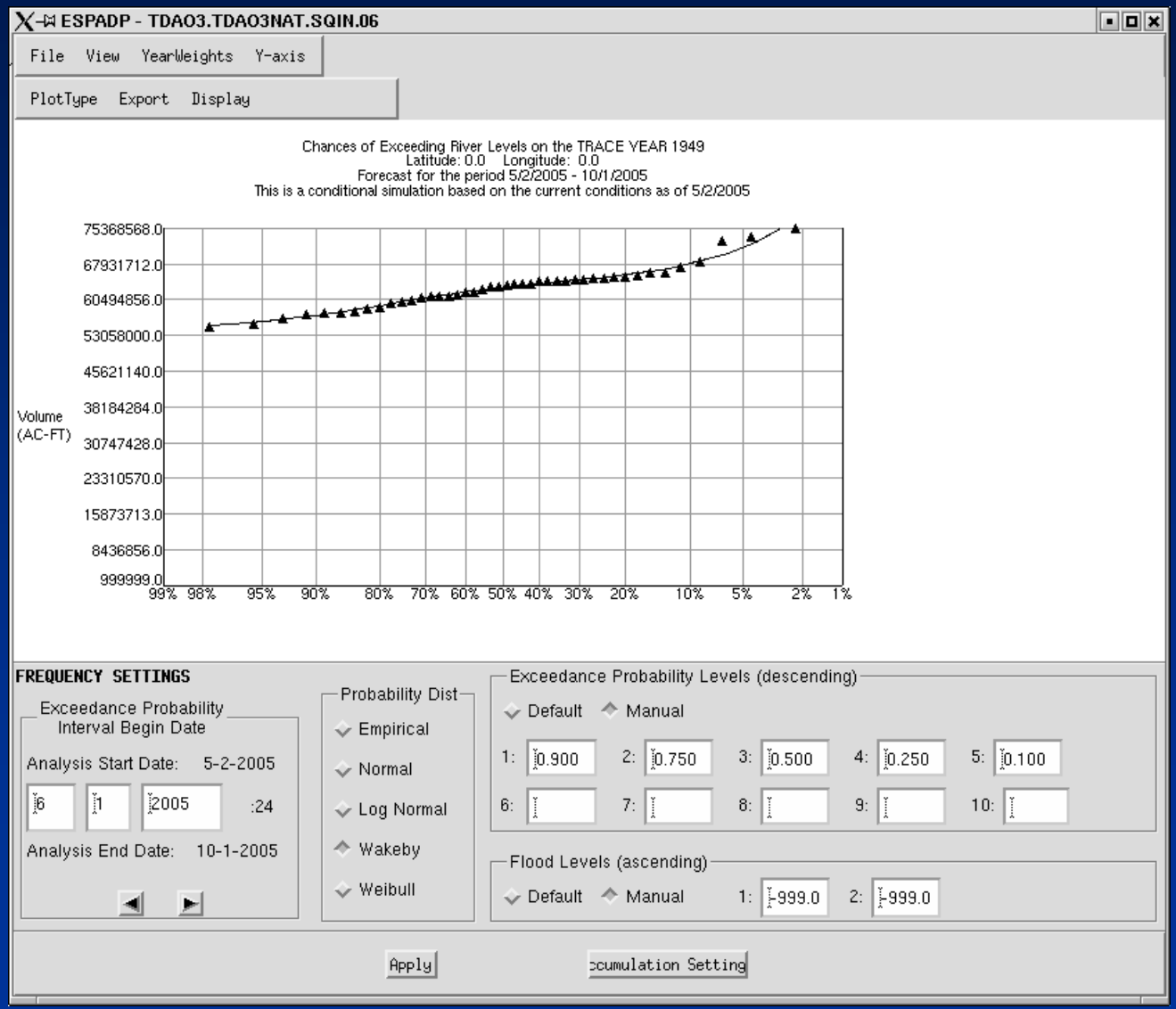
Private Data Sources

Earth Satellite Corporation Utility Forecasts



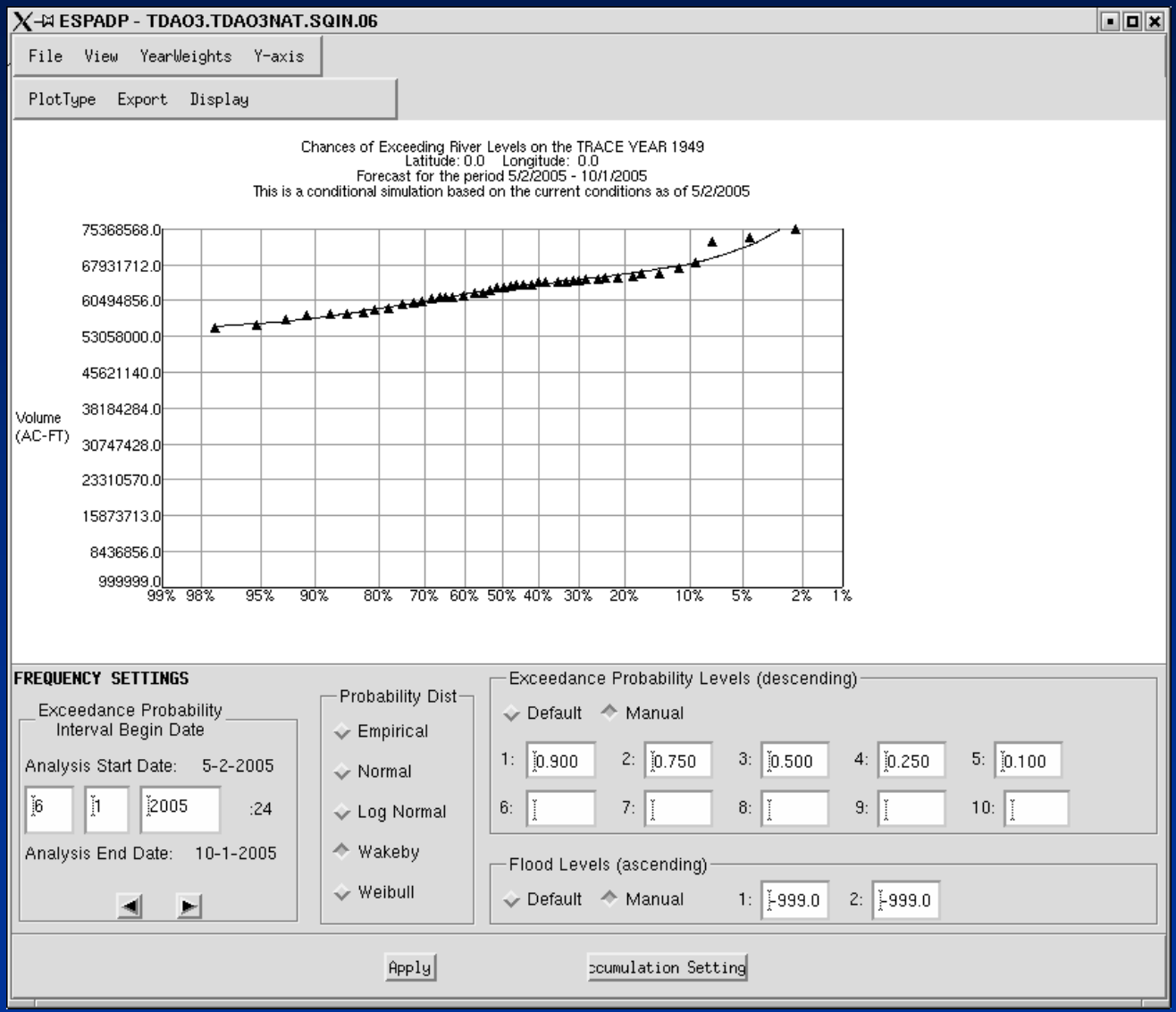
Inflows to the Dalles Dam

Standard ESP Forecasts



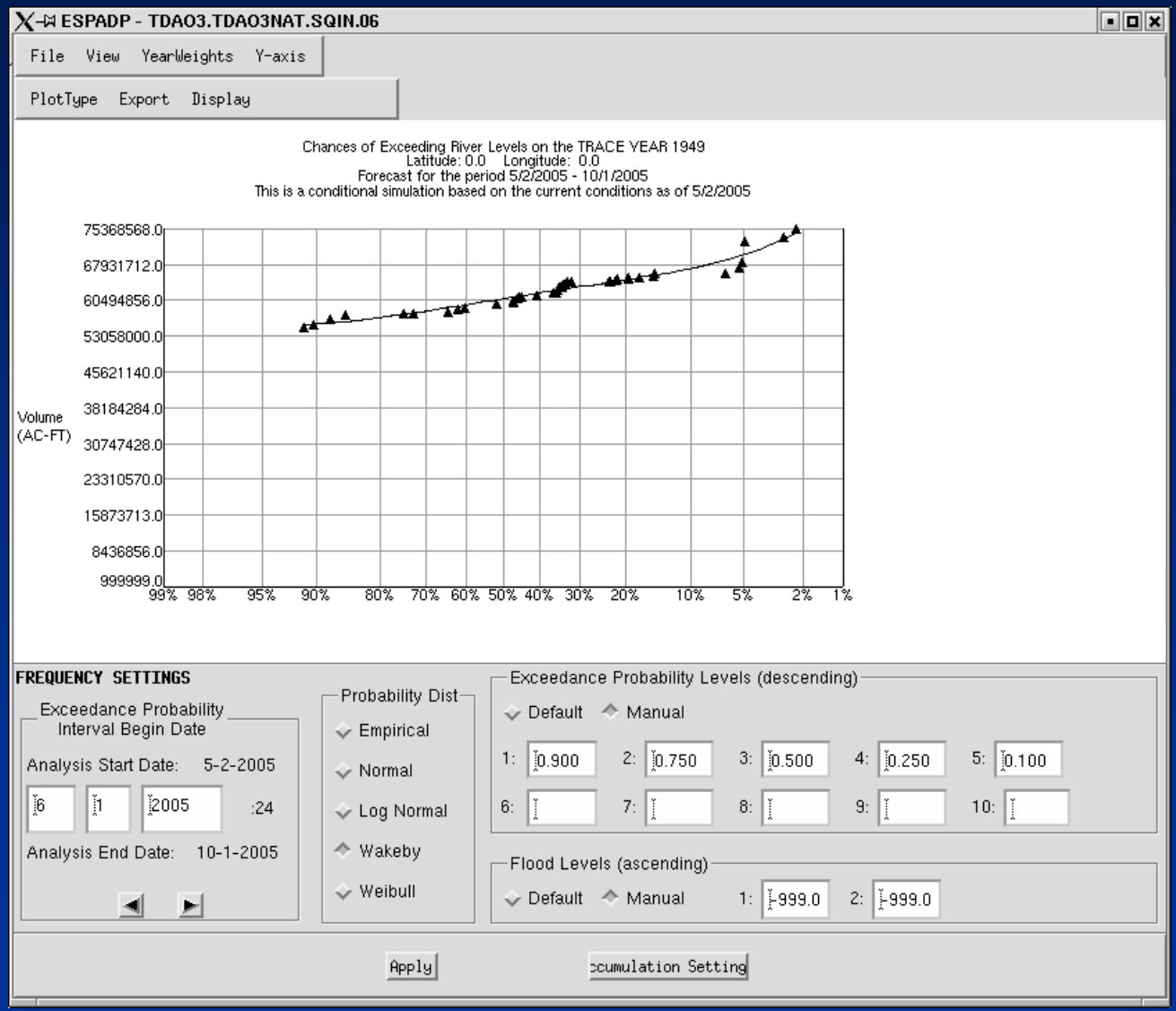
Inflows to the Dalles Dam

ESP Conditioned on CPC Climate Forecasts



Inflows to the Dalles Dam

ESP Conditioned on EarthSat Climate Forecasts



Had Enough?

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